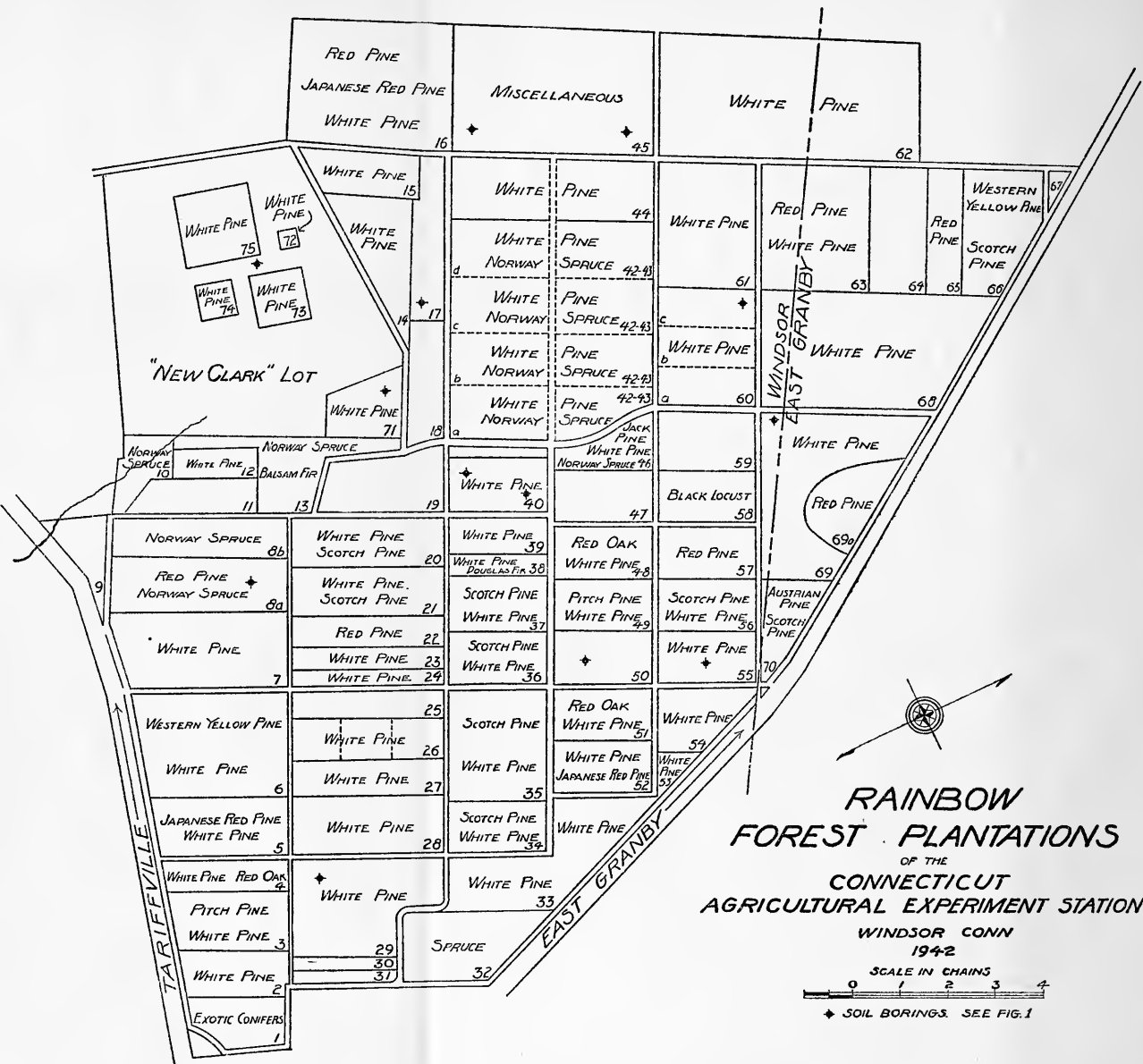


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The Rainbow Forest Plantations

Report of Progress, 1942

HENRY W. HICOCK

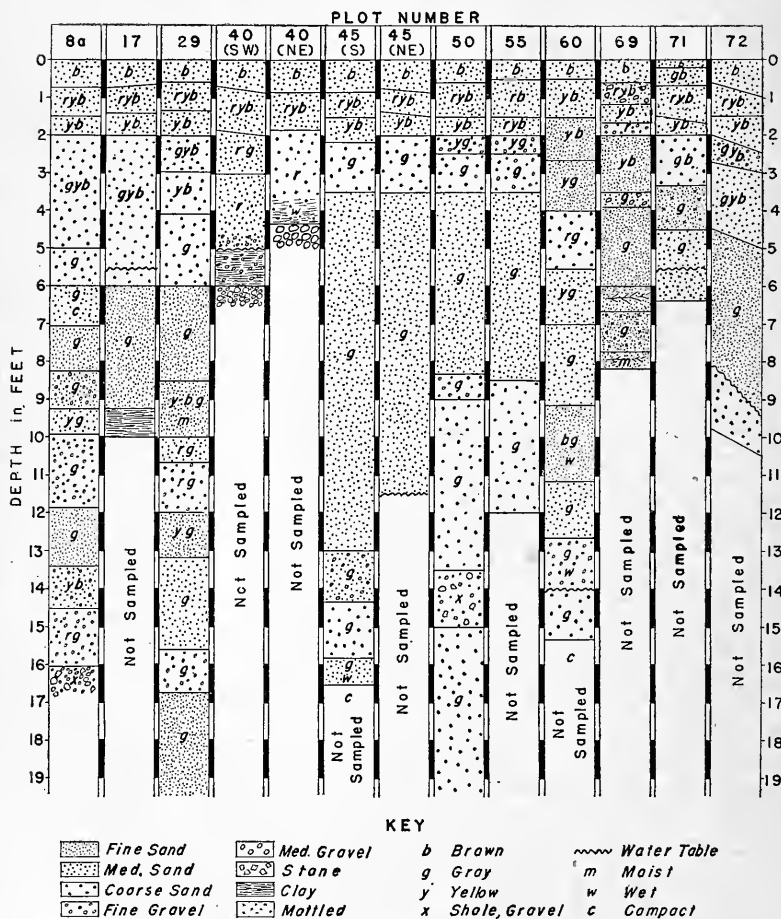


Connecticut
Agricultural Experiment Station
New Haven

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REPRESENTATIVE SOIL PROFILES IN THE RAINBOW PLANTATION



Diagrammatic sketch of soil profiles based upon borings made with an 8-inch post hole auger to a maximum depth of 19½ feet (the limit of the auger shank).

On certain plots, notably 8a, 40, 45 and 60, depth of penetration was restricted by a layer of either gravel and stone or compacted sand. The borings on Plots 8a, 17, 29, 45(s), 50 and 60 were made in May 1938, and those on the remaining plots were made in November of the same year. The water table levels indicated in the chart are as found on those dates. The presence of tree roots below 4 feet was observed in only two places, Plot 69 and in one of the borings on Plot 72. The approximate locations of the borings are shown on the accompanying map.

The Rainbow Forest Plantations¹

Report of Progress, 1942

HENRY W. HICOCK

HISTORY AND DESCRIPTION OF TRACT

History of the Tract

The Rainbow Forest Plantations of the Connecticut Agricultural Experiment Station occupy approximately 120 acres in the towns of Windsor and East Granby, about one-half mile west of the village of Rainbow. Of this area, 110 acres in Lockwood Field and Clark Field were purchased prior to 1905. The balance of 10 acres in the "New Clark" lot was purchased in 1929, to round out the holdings.

At the time of the first purchase (1900 to 1905), the land had been abandoned for ordinary agricultural crops because of its poor quality. The cost was therefore very low. During the past 35 years, however, there has been a marked increase in the amount of tobacco raised in the Connecticut Valley. Tobacco is a valuable crop which requires very intensive cultural methods. Land formerly considered too poor for such crops as corn, potatoes, etc., is now used for tobacco. This change in crops has caused a marked increase in land values in the region.

Topography and Soils²

The tract lies on a practically level bench about 100 feet in elevation above the Farmington River and 160 to 180 feet above sea level. The soil on the major portion of the area is what was originally mapped by the U. S. Bureau of Soils in 1899 as "Windsor sand"; this name was changed in their Bulletin 96 to "Merrimac coarse sand." It is part of a deep deposit of glacial outwash material which forms an extensive plain in this portion of the State. The surface soil contains sufficient organic matter to give it a medium brown color to a depth of 5 to 7 inches. The subsoil is of a yellowish color to a depth of about 3 feet, where it grades gradually to the dull gray which is imparted to it by the undisclored coarse granules of impure quartz sand which predominate. At lower depths, the stratified material varies in color from gray through yellowish brown to reddish brown or gray, and in texture from fine sand to small gravel. On Plot 40, a gravelly clay layer occurs at a depth of 4 to 5 feet, resulting in a considerably

¹ The author wishes to express his appreciation to all who have worked with him in the preparation of this report. Certain sections were written by members of other departments of the Station and to them specific credit has been given. Other names which should be included are Dr. A. Raymond Kienholz and Messrs. A. R. Olson and E. M. Stoddard whose assistance on many phases of the work is gratefully acknowledged.

² Notes on soils furnished by Dr. M. F. Morgan and Dr. H. A. Lunt, of the Department of Soils, Connecticut Agricultural Experiment Station at New Haven.

higher moisture content of the soil immediately above the clay than is found at similar depths elsewhere on the tract.

The water table varies from about 5 feet in the east end of Plot 17, to 13 or 14 feet in Plot 60, and more than 20 feet in the vicinity of Plot 29.

The average analysis of the surface 6 or 7 inches of mineral soil is as follows:

pH	4.7 percent	Moisture equivalent	7.6 percent
Total nitrogen	0.05 percent	Total sands	89.1 percent
Total carbon	1.75 percent	Silt	5.4 percent
Nitrogen: carbon	1.34 percent	Clay	5.5 percent
Loss-on-ignition	2.9 percent	Total colloids	7.3 percent

The total colloid content does not change appreciably to a depth of 14 to 16 inches. Below this, it diminishes quite rapidly to less than 2 percent at 24 inches. Nitrogen and carbon drop rapidly below the 7 or 8-inch level.

In small local areas near the western border of the tract, especially in Plots 16, 44 and 45, the soil is unusually coarse and low in colloids. In places, there is practically no surface soil. The water table lies at about 17 feet. On such areas all plant growth is either much stunted or is altogether lacking. The change from these areas to those that support a normal plant growth is very abrupt. Trees planted on the sterile spots either grow very slowly or do not survive at all. Red pine seems to make a little better growth on them than does white, but the needles of both are yellow and, in general, the trees are crooked and sickly.

On the higher ground in the northeastern portion of the tract, especially in Plots 68 and 69, the soil is finer in texture, consisting of about 7 inches of medium brown loamy sand surface soil, with a yellow subsoil of a similar texture to a depth of about 2½ feet overlying the unweathered glacial till. The latter is made up largely of a mass of red shale and sandstone rock fragments of moderate size (less than 6 inches in diameter) with a considerable admixture of grayish sand and fine gravel. This soil type was identified in the 1899 Bureau of Soils survey as "Enfield sandy loam" but this name was changed to "Manchester fine sand" in U. S. Bureau of Soils Bulletin 96.

The frontispiece is a diagrammatic sketch of several soil profiles at selected points.

Cover Types

Practically the entire area included in the Rainbow plantations had at some time been under cultivation. This is indicated by the presence of parallel furrows and ridges over most of the tract. Although no cover records are extant, reversion on much of the land included in the first purchases (1900 to 1905) had not progressed beyond the broomsedge (*Andropogon*) stage. (See Plate Ia). The 10 acres

bought in 1929 bore a cover of hardwoods and pitch pine which varied considerably in age but averaged around 50 years.

The natural forest growth of the region is composed of pitch pine and inferior hardwoods, chiefly gray birch and black oak. In places, there is some white pine. Formerly, chestnut was a component of the stand. The quality of site for forest growth is about as low as can be found in Connecticut. Production in volume is consequently low.

Land abandoned for agricultural purposes in this region usually first seeds in to herbaceous plants, of which broomsedge is the most important component, followed by gray birch and pitch pine. Later stages of reversion usually show a diminution of gray birch and an increase of inferior oaks, red maple and pitch pine. If fires are kept out and a seed supply is at hand, there is likely to be white pine in the mixture. Some 25 species of trees are native to the region, but it is estimated that various species of oak, red maple and pitch pine constitute more than half of the older stands in most cases.

The Forest Plantations

Artificial forest regeneration was begun on the area in 1901 following a plan made for the Station by W. L. Hall of the U. S. Forest Service. The original plan called for a very elaborate series of experiments in seeding and planting. Many of the earlier experiments, especially those in seeding both hardwoods and conifers and in planting hardwoods, resulted in complete failure. No reference will be made to these in this report unless some trace of them can still be found on the ground. Details concerning them may be found in the annual reports of the Station for the years 1907 and 1912. The oldest stands on the tract at present resulted from plantings made in 1902.

For a number of years a nursery was operated in connection with the tract, but this practice was later abandoned and stock procured from other sources. About 100 acres, or 90 percent of the area, has been artificially regenerated, most of it prior to 1915.

As a protection against fire and to facilitate operations, an elaborate system of fire line roads is maintained. These are harrowed at intervals of one to three years. The plantations are under the general care of a local resident who attends to the various operations under supervision of members of the Station staff. Owing to the fact that the area is cut up into a large number of small plots and planted to a number of species, no profits can be expected from the investment, although expenses have been reduced somewhat by the sale of materials.

Prior to 1932, work had been confined almost wholly to planting, weevil control, release cuttings and a very small amount of thinning. Owing to economic conditions in 1932, it was possible to carry out some much-needed thinnings in the older plots. The only cost of this was for marking and supervision, the materials removed being taken in payment for the labor of cutting. Under this arrangement, about 225 cords of wood were cut. Of this, 150 cords were from trees which

had been planted. The balance was birch, pitch pine and other species removed in release cutting or other operations. Some 30 local families were, in this way, each able to secure six to eight cords of fuelwood without money outlay.

In 1934 the Civilian Conservation Corps built Camp Britton on Station land in Windsor. From this camp details were available to the Station for additional work in pruning, thinning and other cultural operations.

DESTRUCTIVE INFLUENCES

Insect Pests¹

Inasmuch as most of the plantings have been made with coniferous stock, mainly pine, the insect pests of conifers are more conspicuous than those attacking other trees. The stands are young, relatively speaking, and hence the more serious pests are those which affect trees under 40 years of age.

The white pine weevil (*Pissodes strobi* Peck) is without doubt the most important insect enemy in the tract and has affected all the white pine stands in some degree. Its status as a pest is indicated in the general discussion of the several plots given elsewhere in this bulletin. The extent to which this insect can injure young white pine in this region is shown by the number of trees weeviled in a one-acre plot planted in 1931 with 2-1 stock and a 6 by 6 foot spacing. No weevil control was carried out in this plot, and the brush was kept down by frequent cutting. On January 1, 1940, there were 617 trees standing, the average height being 7.0 feet. Forty-nine percent of the trees have been weeviled once, an additional 34 percent weeviled twice, 6 percent weeviled three times, and 0.5 percent weeviled four times, leaving about 10 percent of the trees uninjured by the weevil eight years after planting. The weevil attacks Norway spruce to some extent but in this tract the injury to this host has been negligible.

The pales weevil (*Hylobius pales* Herbst) is present in the tract and injures young conifers planted the spring after pine has been cut off an area. In the winter of 1930-31 Plot 72, containing a few pitch pines in a predominantly hardwood cover, was cleared preparatory to planting. Several fresh pitch pine stumps were left on the west side of the plot. In the spring of 1931 the block was planted with 2-1 white pine stock. During this spring and the subsequent fall the pales weevil severely injured the trees near the pitch pine stumps, killing 90 of them. These dead trees were replaced the following spring and no further injury occurred. In the spring and fall of 1939, following salvage of hurricane-felled timber, pales weevil injury to young pine reproduction occurred in some plots.

Bark beetles of the genus *Ips* have been injurious to pines at times. On one occasion a group of red pines about 18 feet high in the

¹ Notes on insect pests contributed by Dr. R. B. Friend, Department of Entomology, Connecticut Agricultural Experiment Station at New Haven.

center of a plot were attacked and about 10 of them killed. No reason for the susceptibility of these particular trees to attack could be determined. Following the hurricane of September 21, 1938, the wind-thrown timber offered an excellent opportunity for these beetles to become abundant in 1939. During the latter year a number of apparently healthy trees were attacked and killed. In three plots of red and white pines examined in the fall of 1939 there were 2,500 trees, of which 119, or about 5 percent, had been attacked, 36 of them being dead. *Ips pini* Say, *I. grandicollis* Eichh. and *I. calligraphus* Germ. were present.

The mound-building ant (*Formica exsectoides* Forel) is quite common in the tract, its abundance possibly favored by the sandy nature of the soil. This ant kills young pines around its nest, creating bad "holes" in plantations. Several red and white pine stands have been infested.

The pitch pine, which is native to the region and has been planted in some plots, has been attacked by the needle miner (*Paralechia pinifoliella* Chambers) and a scale (*Matsucoccus gallicolus* Morr.). These two insects have caused considerable browning of the foliage in recent years, and the scale was very abundant in 1939. The scale also occurs, sparingly, on western yellow pine.

Several other pine-infesting species, some of them potential pests, are quite common, although none has been very injurious to date. The pine bark aphid (*Pineus strobi* Htg.) is very common on white pine, particularly on trees along roads and bordering openings in stands. The pine spittle bug (*Aphrophora parallela* Say) and the pitch mass borer (*Parharmonia pini* Kell.) are frequently found on white and Scotch pines. The pine root collar weevil (*Hylobius radicis* Buch.) infests some of the western yellow pines, but this species is degenerating from other causes.

The Norway spruce has been infested with the spruce gall aphid (*Adelges abietis* L.), and some trees, most of them overtopped, have been injured quite badly. The spruce shows immunity to gall aphid attack to such an extent that the insect cannot be considered a serious economic factor in this case.

The black locust has suffered in the past from attack by the locust borer (*Cyrtene robiniae* Foerster), and this insect is quite common in locust sprout growth at the present time. Whether or not the borer will injure these sprouts as severely as it injured the trees originally planted remains to be seen.

The gypsy moth was discovered in the tract in 1938 when one egg mass was found on an oak tree. An attempt will be made to eradicate the infestation. This insect would be very injurious to mixed pine and hardwood stands if it became abundant, since much of the hardwood is oak and birch.

Fungous Diseases

To date there have been no serious attacks by parasitic fungi on planted trees, with the exception of the chestnut bark disease, *Endothia parasitica* (Murr.) A & A which is common throughout the range of chestnut.

In the fall of 1938, the roots of several white pines and one Norway spruce were found to be heavily infected with a root-rot, *Fomes annosus* (Fr.) Cke. Fruiting bodies were found. A similar fungus was reported in Windsor (not at the Rainbow tract) in 1906 but could not be positively identified, as the fruiting stage was not found. This disease will be watched closely and, should further outbreaks occur, a study will be made of its life history and methods of control.

Several species of *Peridermium* have been identified from time to time but attacks have been confined to scattered individual trees and cannot be classed as serious. The white pine blister rust, *Peridermium strobi* Kleb., which causes severe damage to white pine in some sections of Connecticut, has not been found on this species at Rainbow. Little trouble is anticipated from this disease as the alternate host grows very sparingly in the region.

Other miscellaneous fungi have been collected on the tract but, since these do not seem to be of economic importance, no specific reference is made to them. On the whole, the general health of the plantations has thus far been very good.

Hurricane Damage

The hurricane, which swept over New England on September 21, 1938, destroyed or damaged about 25 percent of the experimental plots. The older stands were most severely injured, some of them being wiped out completely.

The problems confronting the Station in the salvage operations were two:

1. *To get rid of wind-thrown and injured trees in order to reduce the fire hazard and to leave the tract in suitable condition for further experiments.*

The clean-up work was done under Station supervision by W. P. A. and C. C. C. details and by local labor. On areas where all the trees had to be salvaged, the brush was piled and burned. Where only a part of the trees were injured, brush was lopped and scattered.

Some 80,000 board feet of logs, from 5 to 10 inches in diameter inside bark at the small end, were sawed on a share basis by a local millman. Smaller material was made into posts and cordwood, most of which was given away.

2. *To secure specific and general information of value in the future management of the Rainbow tract or in the general field of forestry.*

Data were taken or observations made as indicated below. In some cases, the data or observations were completed and are described in this paper, but in others they are as yet incomplete and will be reported on at a later date.

a. For the purpose of determining the status of experiments on the tract, an inventory of standing and down trees was taken on most of the older plots. The data so taken were used in computing the tables of volume which appear later under "Description of Plots".

b. Taper measurements were made on over 500 white pine stems. The data, together with some from other sources, have been incorporated in "Volume Tables for Plantation Grown White Pine" which was published as Station Bulletin 427, in June, 1939.

c. Materials for a series of standard timber tests were collected from eight species planted on the tract. As this bulletin goes to press, the tests are being made and the results should be ready for publication within a year.

d. The exposure of many root systems afforded an opportunity to observe the distribution of a root rot, *Fomes annosus* (Fr.) Cke. Fruiting bodies of the fungus were found on the roots of all conifers planted on the tract.

e. The Departments of Entomology and Soils of the Station are carrying on investigations, in their respective fields, of conditions resulting from the hurricane. These studies are not complete and will not be reported on at this time.

f. The following rather general observations on hurricane damage to the several species may be of interest. It should be noted that, just prior to the hurricane, there had been an excessive amount of rainfall which probably increased the amount of damage very appreciably.

The older stands, which were most severely injured, were chiefly white pine, and consequently the amount of damage was greatest for this species. In practically all cases the trees were uprooted, with very little breakage of the stems.

The damage to Scotch pine was almost entirely by breakage, most of the trees being snapped off from 2 to 15 feet above ground. It is believed that this was not due so much to weakness of the wood as to the greater holding power of the root systems which show a more extensive development on this site than those of other species. Practically all the older Scotch pine was completely wiped out. Where it was mixed with white pine, the latter was usually not seriously injured, probably because it occupied a subordinate position in the stand.

Damage to red pine was mostly by uprooting although, in a considerable number of cases, the windward side of the stems was broken transversely to the pith at the ground line. This break was followed by a splitting of the trunk to a height of 1 to 4 feet. The

leeward side was not broken in such cases, nor were the roots pulled out.

Injury to other species was mostly by being overthrown completely with little stem breakage.

DESCRIPTION OF PLOTS

The general objective for the plantations is to furnish a field laboratory where the many problems, which arise in connection with the establishment and subsequent care of artificially regenerated stands, may be studied. While the area is under the direct supervision of the Forestry Department, many of the experiments are collaborative enterprises in which the Entomology, Botany and Soils Departments of the Station and the Yale School of Forestry are participating.

Following is a description of the several plots which make up the tract. Much of the material is from a detailed manuscript report made by James H. Hull during the summer of 1936. The plan followed for each of the plots will be:

1. To describe the experiments which resulted in the establishment of the present stand, together with the condition of the planting site if this was recorded. Prior experiments will not be noted unless they have some bearing on the present stand.
2. To note all operations that have been performed which would affect the trees, including the establishment of new experiments.
3. To summarize the results up to the present time.
4. To indicate the probable future use of the plot.

Where volumes are given, they denote the entire peeled contents of the stem, including stump and top. The values were taken from volume alinement charts constructed by the Connecticut Agricultural Experiment Station for red pine (Bulletin 413) and white pine (Bulletin 427).

PLOT 1a. Administration. Area about .2 acre.

PLOT 1. Exotic Conifers. Area about .7 acre.

Planted in April, 1907, with two-year seedlings in pure groups as follows: 600 Austrian pine, 5 by 5 feet; 125 European larch, 5 by 5 feet; 500 Scotch pine, 5 by 5 feet and 130 Scotch pine, 6 by 6 feet. The locations of the several plantings were described rather vaguely and cannot be traced on the ground because a fire in 1911 destroyed about 70 percent of the planted trees. The burned area was replanted in 1913 with seven-year Douglas fir transplants and eight-year Chinese arborvitae seedlings (number of each not recorded). About the same time, a few Japanese red pine were also introduced. Adjacent to the Austrian pine is a little white pine of unknown origin. There was probably no cover on the plot at the time of planting except scattered large pitch pines.

By 1923 estimated losses, excluding those from fire, had been 15 percent for Scotch pine, 50 percent for Austrian pine, 65 percent for European larch, nearly 100 percent for Douglas fir and 100 percent for Chinese arborvitae. The Scotch and Austrian pines were in good condition. The surviving European larch was very irregular in height and the Douglas fir very much stunted. The Japanese red pine exhibited the usual multiple stemmed form (see Plot 5.).

A light thinning was made in the fall of 1932 to favor the best of the Scotch and Austrian pines and the European larch.

In 1936 the Scotch pine averaged 35 feet in height and 7 inches in diameter and was reasonably straight stemmed. Some reproduction had come in, most of it since the 1932 cutting. The Austrian pine averaged 30 feet in height and 6 inches in diameter. The trees were making good growth but the crowns were rather thin. (The Austrian pine on this plot and on Plot 70 seem to be an unusual strain of this species. The trees have thin, narrow crowns and short, twisted needles). Only 20 specimens of European larch had survived, the largest being 30 feet in height and 4 inches in diameter. Two scrubby Douglas fir were found. The Japanese red pine averaged 10 feet tall. The trees were crooked and in most cases had produced multiple stems. Considerable reproduction of this species was found.

Hurricane damage in 1938 necessitated the removal of most of the Scotch, Austrian and pitch pines in the middle of the plot, leaving only a fringe of trees of the several species along the edges. There is probably enough reproduction of several coniferous species on the ground to restock this opening. Future operations will be to maintain the exotics from the original plantings and to bring through the young reproduction in the openings.

PLOT 2. White Pine. Area about .8 acre.

Planted in May 1907 with white pine two-year seedlings spaced as follows: 300, 6 by 6 feet; 330, 5 by 5 feet; 500, 4 by 4 feet and 600, 3 by 3 feet, the widest spacing being nearest the highway. A few red and white oaks from 1902 seeding experiments form a small part of the stand. In 1911 a fire destroyed all the 3 by 3 and 4 by 4-foot plantings and practically all of the 5 by 5-foot planting. The burn was replanted in the spring of 1913 with stock from Plot 62, which was also planted in the spring of 1907 with two-year seedlings. The spacing used was about 5 by 5 feet. All the trees on Plot 2 are, therefore, the same age from seed. A second fire in 1923 destroyed about one-tenth of an acre of the 1913 planting, and this has not been replanted. Encroaching volunteer hardwoods were removed in 1919. While no record was made of the cover at the time of planting, it seems probable that there was very little except the oaks from previous experiments. The value of the plot as an experiment in spacing was, of course, destroyed by the fire.

While the trees on the burned and unburned sections are the same

age from seed, those on the former were set back very appreciably in moving. In 1923 the trees planted in 1907 were 13 feet tall, and those replanted from Plot 62 on the burn were only 5.5 feet.

The trees on both sections have developed irregularly in height and are quite free of weevil damage. There is some reproduction of white, Jack and Scotch pine in the opening caused by the 1923 burn but not enough for complete stocking. There was very little hurricane damage.

Table 1 shows the volume of the stand, as of the fall of 1939 after a small amount of salvage material had been removed.

TABLE 1. VOLUME OF WHITE PINE ON PLOT 2, FALL OF 1939

D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	12.0	104	....²
2	18.5	186	39.0
3	23.3	239	136.1
4	26.8	218	255.1
5	29.0	204	406.0
6	30.5	151	437.9
7	31.7	61	254.4
8	32.5	24	132.0
9	33.0	4	28.0
10	33.5	...	8.7
Total	...	1,192	1,697.2

¹ From Chart I, Bulletin 427 of the Connecticut Agricultural Experiment Station.

² Below Limits of Volume Table.

Future operations will consist of thinning by the crop tree method, accompanied by pruning of the selected trees.

PLOT 3. Pitch Pine and White Pine. Area about 1.3 acres.

In April 1902 pitch pine seed was sown broadcast on cultivated strips, 1½ feet wide and spaced 4 feet apart, at the rate of 2 pounds per acre on half the plot nearest the highway, and at the rate of 1 pound per acre on the other half. Seedling counts made that fall showed an average of 10,000 trees per acre for the 2-pound sowing and 2,500 per acre for the 1-pound sowing. In 1906 there were 5,000 living trees on the plot, height 26 inches.

In 1923 the 2-pound sowing averaged 6,000 living and 4,000 dead trees per acre. The average height was 17 feet, and D. B. H., 2 inches. Distribution was fairly even. The 1-pound sowing averaged 1,200 trees per acre. The average height was 15 feet, and D. B. H., 3 inches. Distribution was quite uneven. In 1934 the trees averaged 22 feet tall and 4 inches D. B. H.

The experiment in reproducing pitch pine by broadcast seeding on cultivated strips was successful, although the number of trees which

resulted was not in proportion to the amount of seed used on the two sections. The development of the trees, however, has not been satisfactory. Growth has been much slower than for other species planted at the same time (see Plots 23, 24, 25 and 28) and the trees are "scrubby" in appearance.

By 1932 some white pine reproduction had become established on the plot and it was decided to use the pitch pine as a protective cover for this species. Cuttings were made in 1932 and in 1936, reducing the density of the pitch pine canopy to about .5. Pitch pine seems to be an excellent nurse crop for white pine. If its canopy is not too dense, the white pine will grow through it without being appreciably retarded in height growth or damaged by "whipping". The nurse crop gives high protection against weevil injury (see Plot 49).

A count of white pine seedlings on the plot in the fall of 1937 showed this species present in the following numbers and sizes:

Height of trees, ft.	Number of trees
0- $\frac{1}{2}$	712
$\frac{1}{2}$ -1	32
1-2	61
2-4	72
4-8	100
Over 8	53
Total per plot	1,030
Total per acre	792

There had been practically no weevil injury to the white pine. In addition to this species, there were also volunteer seedlings of Scotch and pitch pine as well as hardwoods.

In anticipation of a heavy seed crop maturing in 1938, the mineral soil was exposed on a large number of small areas (5 square feet in area). No seedlings had come in on these up to October 1940. It seems probable that the hurricane may have dispersed the 1938 seed crop so widely that none was available locally. Hurricane damage to the pitch pine cover or to the reproduction already established was negligible.

Release cuttings in the pitch pine cover will be repeated as often as needed to favor the new crop of trees.

PLOT 4. White Pine—Red Oak—Scotch Pine. Area about .7 acre.

Planted in the spring of 1904 with white pine two-year seedlings and red oak acorns (three in a hole), spaced 6 by 6 feet; every other row solid oak, and the rows between, oak and pine alternating in the row. (Compare with Plots 48, 50 and 51.) Losses for both species were small for the first three years but subsequently rodents kept the oak cut back so that it became overtopped by the pine. On the south half of the plot Scotch pine was introduced about 1914 to replace the oak and improve the density.

The development of this stand has been that of a white pine stand with a 12 by 12-foot spacing. In 1936 this species averaged 35 feet in height and 7 inches D. B. H. The trees were broad-crowned with heavy side branches, and had been very severely damaged by weevil. An occasional red oak had grown normally and was approximately the same height as the pine, but most of the oaks which had survived were badly suppressed and only 5 to 10 feet tall. The Scotch pine did well at the start and at the end of ten years had nearly caught up to white pine in height although it was quite slender. The handicap in age was too great, however, and during the succeeding 13 years most of it had been crowded into an intermediate position or killed. This species is quite intolerant of shade and, if crowded severely, becomes malformed and quickly drops back into a subordinate position.

On account of the generally poor quality of the white pine as a result of wide spacing, the experiments as described above were abandoned. During the salvage operation after the hurricane, which caused negligible damage on this plot, four areas, each approximately 75 feet square, were clear cut in such a way that each was bordered by two rows of white pines. Brush was piled and burned.

Table 2 shows the volume of white pine on the plot as of the spring of 1939.

TABLE 2. VOLUME OF WHITE PINE ON PLOT 4, SPRING OF 1939

D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Remarks
1	11.5	1	....²	
2	17.4	3	.6	
3	22.2	1	.5	
4	25.8	16	17.9	
5	28.9	19	37.5	
6	31.4	27	81.4	
7	33.6	40	174.5	
8	35.3	42	250.0	
9	37.0	64	492.5	
10	38.4	53	520.0	
11	39.7	33	371.5	
12	40.8	22	325.5	
13	41.8	1	17.7	
14	42.8	1	21.0	
15	43.8	1	24.4	
Total	....	324	2,335.0	

¹ From Chart I in Bulletin 427 of this Station.

² Below Limits of Volume Table.

The results of natural seeding of pine on these clearings will be watched and, if unsatisfactory, planting will be resorted to. Since the oak has sprouted quite vigorously, a number of weedings will be needed to favor any coniferous reproduction, natural or planted, which may be established.

PLOT 5. Japanese Red Pine and White Pine. Area about 1.4 acres.

Planted in May 1910, with Japanese red pine two-year seedlings spaced 6 by 6 feet. There was probably very little competing cover on the ground at the time of planting. Losses during the first year, amounting to 60 percent, were replaced with three-year transplants of the same species in May, 1911. Further losses were replaced with white pine four-year transplants in the spring of 1913. The stand in 1913 was made up of 70 percent Japanese red pine and 30 percent white pine, with a few white oaks and catalpas from previous experiments. A weeding operation removing competing hardwoods was performed in 1921.

By 1923 the Japanese red pine had reached a height of 8 feet, and the white pine, 7 feet. Weevil damage had amounted to 10 percent in the former and 45 percent in the latter.

Almost without exception the Japanese red pine developed multiple stems. In 1924 an attempt was made to correct this habit by lopping back all but one stem to about 5 feet above ground. The results were unsatisfactory because the side branches turned upwards and soon caught up with the uncut stems. This species bears seed very prolifically and many seedlings of various sizes are to be found all over the plot. A large percentage of these occur directly underneath the crowns of the parent trees and are very spindling. In 1928, 24 of the older Japanese red pine trees were removed in an attempt to increase the vigor of the seedlings beneath. The results were not satisfactory, little improvement being apparent after nine years.

Japanese red pine is not a promising tree for reforesting sandy soils. If grown in the open, it produces multiple stems. Under severe competition it will usually produce only one stem but this is likely to be crooked or extremely slender (see Plots 19 and 52).

Although the white pine was severely weeviled during early life, recovery from injury has been very rapid and the percentage of trees of satisfactory form is quite high. This excellent recovery was probably due to the fact that, during the first 10 years, it was just a little below the Japanese red pine in height. By 1934 the white pine had assumed the lead and was 20 feet tall, as compared with 18 feet for the Japanese red pine. The lower side branches on the white pine were quite small.

The only hurricane damage to the plot was the overthrowing of a number of very spindling Japanese red pine and, in 1941, this species was rapidly being subordinated to the white pine.

In view of the poor results with Japanese red pine, further work with this species will be discontinued and the plot used for other purposes. An effort will be made to establish a white pine stand composed of various aged groups by natural seeding. This will be done by removing the Japanese red pine in several operations prior to white pine seed years and exposing the mineral soil.

PLOT 6. Western Yellow Pine and White Pine. Area about 2.7 acres.

Planted in April 1908 with western yellow pine two-year seedlings, spaced 5 by 5 feet. In 1912 and 1913, losses, which had amounted to 45 percent, were replaced with white pine four-year transplants. At this time the western yellow pine averaged 1 foot tall. In 1921 all encroaching hardwoods were removed.

In 1923 one-third of the plot was occupied by western yellow pine and one-third by white pine. The balance was open area caused by losses. Both species averaged 6 feet tall. Sixty-five percent of the white pine had been weeviled.

By 1934 the white pine had attained a height of 19 feet and the western yellow pine, 15 feet. Due to the open character of the stand and to weeviling, the former is generally of poor form with large crowns. The western yellow pine has not done well. There was a heavy loss during the first four years which was probably due to using small stock. Since that time, the number of trees has been gradually diminishing. The trees which have died have all exhibited the same symptoms. There is a general decline in vigor marked by a slowing up of growth and thinning of the crowns, with death following in about five years. A rust, *Peridermium pyriforme*, has been found on some of the trees but it seems improbable that this could have been the cause in all cases. No fruiting specimens of this fungus have been found in recent years. The species is intolerant, and crowding by white pine may have caused some losses. On the other hand, many trees have died which were entirely isolated. Perhaps a more logical assumption is that the species is not well suited to thin sandy soils such as are found on the Rainbow tract. A few trees attained a height of 30 feet in 30 years but, in general, height growth has been much less. Western yellow pine was also planted on Plot 66 in 1908 and here it has done somewhat better than on Plot 6.

In the fall of 1937 it was decided to use the plot mainly for an experiment in the natural seeding of white pine. Such western yellow pines as were in vigorous condition were favored by removing adjoining trees to completely isolate their crowns. Over most of the area there were small irregular openings caused by losses. These were cleared of all tree growth and, in some cases, enlarged. Prior to removing the trees, the soil was worked over with a mattock. The plan followed in making the openings was to make one dimension from 20 to 25 feet (between crowns). The other dimension was whatever conditions on the ground dictated. The tops of the cut trees were lopped and scattered over the scarified soil. About 160 well-formed white pines in the uncut strips between the open areas were released and pruned to one-third the total height. Pruning was done with a curved saw and the limbs were cut off flush with the bole, removing the "collar".

One and one-half pounds of white pine seed, collected on the tract, was sown in the openings on a strip extending across the north end

of the plot and 100 feet deep. Hurricane damage on this plot was negligible.

Observations made in October 1940 showed some white pine seedlings 2 to 5 inches tall in most of the openings, with an appreciably greater quantity where the seed was broadcast in 1937. Close pruning resulted in complete occlusion of the branch stubs, in many cases after only three years.

Future management of the plot will be for the purpose of developing by artificial seeding a white pine stand composed of trees of several ages and to favor the healthy western yellow pine.

PLOT 7. White Pine. Area about 2.3 acres.

Planted in September 1913 with white pine three-year transplants as a test of fall planting. The spacing was recorded as 6 by 6 feet, but averaged somewhat less. The experiment was very successful, the survival being about 95 percent. Since the planting was done by two men in one day, it is inferred that there was little competing cover on the ground at the time of planting. Some chestnut trees from experiments started in 1902 and 1903 still persist but have had no effect on the development of the pine. A few Scotch pines have become established near Plot 23 by natural seeding. A number of weevil cutting operations were carried out during the first 15 years after planting, and the plot was thoroughly cleaned of birch and other competing hardwoods in 1921.

In 1923 the trees varied from 2 to 10 feet in height, averaging 6 feet. This variation is somewhat unusual in planted stands and was probably due partly to weevil injury, which amounted to 60 percent, and partly to the fact that some of the trees came out of the stagnation period sooner than others. The irregularity was still marked at the time of closure in 1934 when the trees averaged 18 feet in height and 4 inches D. B. H. Side branches were mostly quite small.

Under the conditions as described above, over two-thirds of the trees had been weeviled, but by 1936 recovery from injury had been very good and there were more than 300 trees per acre with straight boles and good crowns. Most of these were in a slightly subdominant position.

A thinning was carried out on the plot in 1936. As originally planned, this was to be done by the crown method to favor 200 to 300 selected trees per acre. Through a misinterpretation of instructions, the marking was much too heavy and, as carried out on the northerly 60 percent of the plot, left the remaining trees with crowns isolated from each other. The amount taken out was reduced on 40 percent of the plot nearest the highway, and the resulting stand more nearly conforms to the original plan. A considerable sun scald occurred on the more heavily thinned portion.

The 760 selected trees were pruned to an average height of 10 feet (a little more than half the total height). Sixty percent of the

branches removed were alive. A small amount of pruning on a few selected trees had been carried out in 1929. All pruning was done with curved hand saws. During the four years after the 1936 pruning, many of the scars completely healed over (Plate II, Figure a). Damage done by the hurricane was negligible on this plot.

Table 3 shows the volume of the heavily thinned and moderately thinned portions of the plot as of the fall of 1939.

TABLE 3. VOLUME OF HEAVILY THINNED AND MODERATELY THINNED PORTIONS OF WHITE PINE ON PLOT 7, FALL OF 1939

Heavily thinned portion				Moderately thinned portion			
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	
1	9.5	33	— ²	10.0	32	— ²	
2	14.7	89	15.1	15.0	79	14.2	
3	18.8	156	71.8	19.2	126	60.5	
4	22.2	196	176.4	22.5	197	193.3	
5	24.5	167	263.9	24.7	194	316.0	
6	26.0	66	164.6	26.3	91	227.5	
7	27.1	12	42.0	27.6	34	122.7	
8	27.8	2	9.6	28.7	6	29.5	
9	28.5	1	6.1	29.6	2	13.6	
Total	....	722	749.5	...	761	977.3	

¹ From Chart I, Bulletin 427, of this Station.

² Below Limits of Volume Table.

No further operations will be needed on the plot for some time. Observations will be made from time to time to determine the growth and behavior of the trees, deterioration of slash, etc., on the two grades of thinning.

PLOT 8a. Red Pine—Norway Spruce—Himalayan Pine. Area about 1.7 acres.

Planted in the spring of 1922 with red pine and Norway spruce three-year transplants, spaced 6 by 6 feet and alternating by rows, except the four rows adjacent to Plot 8b which are pure pine. During the previous winter, all the cover, which was chiefly gray birch, was cut for cordwood. This cover was very unevenly distributed, being dense only at the southerly end. Much of the plot bore little or no cover. It was weeded in 1928.

At the end of the second year the planting was 90 percent complete. The pine averaged 18 inches tall and appeared thrifty, whereas the spruce averaged only 6 inches in height and was of very poor color, except in a few cases where it was shaded by birch sprouts. After five years the pine had increased in height to 30 inches and the spruce to 8 inches.

In 1927 Scotch pine three-year seedlings were planted 6 feet apart in the spruce rows and alternating with the latter. In May 1929, 600 Himalayan pines were also planted in the spruce rows.

By 1934, the mixed portion of the plot had, for practical purposes, developed into a pure red pine stand, spaced 6 by 12 feet, with heights averaging 10 feet and D. B. H., 2.5 inches; losses were under 10 percent. Losses in the spruce had amounted to 50 percent; heights averaged 2 feet, with an occasional individual attaining a height of 10 feet. Losses in the Scotch pine had also amounted to 50 percent. The trees averaged 4 feet in height but were very slender and probably will not survive. A few of the Himalayan pine had survived; average height, 1 foot.

The behavior of the spruce has been, in all respects, similar to that on Plot 69 where this species was planted in the open with white pine.

The results obtained by using Scotch pine as a filler in a red pine stand five years older were not what was anticipated. On Plots 35, 36 and 37, this species was successfully used to fill gaps in white pine plantings established five to eight years and caught up with the latter in about 15 years. On Plot 8a the Scotch pine is just about persisting after more than 10 years. The reason for this difference appears to be that the period of stagnation after planting was much less for the red pine than for the white pine. The handicap was too great to be overcome by three-year Scotch pine seedlings.

To date there has been very little difference in the development of the red pine on the mixed and pure sections of the plot. On the latter the trees are just closing, while on the former they are closing only in the rows.

In 1931 a replicated series of experiments in the fertilization of individual trees was begun on red pine in the mixed portion of the plot. One hundred and forty-two trees were used. The fertilizers applied were lime, nitrogen, phosphorus, potassium and humus, either singly or in combination. From 15 to 20 trees were included in each treatment, and a like number were tagged and left untreated for controls. Measurements to determine the height and diameter growth of the trees for the five years prior to treatment were made in 1931. Measurements to determine current growth have been made at three-year intervals since that time. Up to the present no definite conclusions have been reached as to the results of treatment.

PLOT 8b. Norway Spruce. Area about 1.3 acres.

This plot was cleared of brush during the winter of 1921-22, with Plot 8a, leaving a few scattered white pine about 15 feet tall which may have originated from a seeding experiment in 1902. The brush cover was very irregular. In some places it was very dense gray birch and in others it was very thin or lacking entirely.

In the spring of 1924, the area was planted with two-year Norway spruce seedlings spaced 5 by 5 feet. Not over 10 percent of these survived the first year, and in 1926 the area was replanted with four-year Norway spruce transplants spaced 8 by 8 feet. Weeding operations were carried out in 1928 and 1936.

Except on the areas which were almost entirely open at the time of planting, most of the spruce has survived, but competition with brush and with the older pine trees has been very strong and most of the trees are flat-topped and growing very slowly. An occasional individual is doing fairly well. The spruce that has survived on this plot is better than that on Plot 8a where it was planted in the open but is not considered to be in satisfactory condition after 17 years. On thin soils, such as are found on the Rainbow tract, spruce needs cover for the first few years after planting in order to get established. Low cover, such as was on Plot 8b, does not seem to be as satisfactory as the higher cover on Plots 10, 13, 42 and 43.

Owing to the considerable failures which have occurred and the generally poor condition of the spruce, the experiment with this species will probably be abandoned. A portion of the plot is now being used for administrative purposes. Except for occasional release cuttings to free the better spruce, no silvicultural operations are planned. Negligible damage was caused by the hurricane.

PLOT 9. Administration.

PLOT 10. Norway Spruce and Hardwoods. Area about .7 acre.

Planted about 1921 with Norway spruce under a stand of old growth chestnut. The spacing was irregular but averaged about 8 by 8 feet. The chestnut stand was evidently rather open over a considerable portion of the plot because, when the chestnut was removed in 1922, there was a mixed stand of oak and other hardwoods up to 10 inches in diameter on the ground. A year later the hardwoods were thinned lightly to favor the spruce.

In 1932 it was evident that the spruce was suffering from too much competition, especially at the south end where the hardwoods were in greatest abundance. In the winter of 1932-33 a heavy cutting was made, removing practically all the larger hardwoods and leaving the younger trees, which were somewhat taller than the spruce, to form a mixed stand. At this time, the spruce were of two general types which graded into each other; first, those which had not been subjected to severe competition and whose crowns were pyramidal in form and, second, those which had been badly suppressed by hardwoods and were flat-topped and otherwise malformed. Malformation had, to some extent, been accentuated by gall aphids (*Adelges*) which were very bad on some trees.

In 1937, five years after the last liberation cutting, the trees with normal crowns had increased in annual height growth from 7 inches in 1933, to 20 inches in 1937. The increase on the flat-topped trees was from 4 inches in 1933 to 7 inches in 1937. The former are mostly fully dominant and will take care of themselves. The latter are of good color and will probably increase in height growth at a faster rate in the future. The hardwoods are, however, competing rather strongly with them again and further releasing will be necessary. The objec-

tive for the plot will be to develop a mixed stand of spruce and hardwoods and to observe the natural pruning of the spruce by hardwood competition. Damage from the hurricane was negligible.

PLOT 11. White Pine and Gray Birch. Area about .7 acre.

An experiment in sowing white pine seed broadcast under a dense cover of gray birch 15 feet high was carried out in 1902. Although records taken before 1907 showed that "not over a dozen seedlings were ever found" it seems probable that the white pine, which is located at the north end of the plot and which has been referred to as "native white pine" in previous reports, originated from this experiment.

Weeding operations were carried out in 1919 and 1923 to free the pines, some of which were badly weeviled and of poor form. In 1932 all hardwoods on the plot, together with the poorer white pines, were removed leaving a number of well shaped white pines to develop.

An experiment in cutting birch at different times of year and at different heights was begun in 1924 but was abandoned. There was no hurricane damage on this plot.

No definite plan has been made for the future use of this plot but it will probably be used for an experiment in reproducing white pine naturally.

PLOT 12. White Pine. Area about .4 acre.

Planted in April 1902 with white pine three-year seedlings, spaced 5 by 5 feet, under a stand of gray birch 15 to 20 feet tall and about .6 density. Fail places were filled in 1904 with three-year transplants. In 1906 the trees were 27 inches tall. In 1910 all birch was removed from the north half, and in 1911, from the south half. In 1919 and in 1924 the birch was again cut and in the latter year a few pitch pine were girdled. Prior to the removal of the birch in 1910 and 1911, annual height growth was 6 to 10 inches; after removal it was 12 to 24 inches.

In 1923, 85 percent of the trees were still alive and averaged 19 feet in height and 3 inches D. B. H. There had been very little weevil damage; side branches were small and dead for 6 to 7 feet above ground.

In 1924 all branches were removed with an axe, from trees on the north half of the plot, to a height of 7 feet.

In 1932, when the trees had reached a diameter of 6 inches and a height of 20 feet, a medium thinning was made, removing five cords of wood and reducing the number of stems to 750 per acre. There was little evidence of weevil injury above 12 feet and most of the weeviled trees were removed in the thinning. All scars from the 1924 pruning had healed over except where stubs protruded.

In 1934, 171 trees were pruned to a height of 8 feet and in 1936, 180 trees, including most of those pruned two years previously, were pruned to a height of 25 feet, removing about 5 percent of live limbs. The work was done with curved saws and ladders. Practically all the litter from the 1932 thinning had disappeared by 1937.

Prior to the hurricane of 1938 this was one of the best white pine stands on the tract. The trees were straight-boled with small side branches and crowns of sufficient width and depth. The excellent development was probably due, in part, to the use of a rather close spacing and to the presence during the first seven or eight years of a brush cover, which gave ample protection against weevil injury and caused an early differentiation into crown classes.

Table 4 shows the volume of white pine on the plot in September 1934 and in October 1938. Approximately one-half the measurements used for the 1938 computations were taken on felled trees in October 1938; the balance were taken on standing trees in October 1939.

TABLE 4. VOLUME OF WHITE PINE ON PLOT 12, SEPTEMBER 1934 AND OCTOBER 1938

Volume in 1934				Volume in 1938			
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	
1	12.4	19	— ²	12.4	3	— ²	
2	19.0	30	6.4	19.0	19	4.1	
3	25.3	77	47.7	25.3	58	36.0	
4	30.0	107	139.1	31.2	79	106.6	
5	33.3	165	367.9	35.3	126	298.6	
6	35.2	209	700.2	37.8	158	568.8	
7	36.3	102	484.5	39.2	190	969.0	
8	37.1	26	162.5	39.8	74	493.6	
9	37.7	14	110.6	40.3	28	238.0	
10	38.3	2	19.6	40.5	12	124.8	
11	...	...	....	40.6	2	25.0	
12	...	...	....	40.7	2	29.6	
Total	...	751	2,038.5	...	751	2,894.1	

¹ From Chart I, Bulletin 427, of this Station.

² Below Limits of Volume Table.

The severe windstorm overthrew approximately half of the trees. The damage was severe in the center of the plot where most trees had to be cut, thereby destroying the experiment begun in 1902. Two years after the hurricane there was a fair natural stocking in the central opening of thrifty young white pine 2 to 4 inches tall.

Further operations will be for the purpose of reproducing the plot to white pine, by natural seeding if possible, otherwise by artificial seeding or by planting.

PLOT 13. Balsam Fir—Norway Spruce—Hardwoods. Area about 1.2 acres.

In 1910, 71 balsam fir three-year transplants were planted irregularly along the northern borders of Plots 11 and 12, and about 1916

the balance of the plot, except the narrow strip to the west of Plot 12, was planted with Norway spruce, spaced irregularly but averaging about 8 by 8 feet. The cover at the time of planting was pitch pine and hardwoods about 50 years old, although it varied considerably in age over the plot.

By 1923 both planted species averaged 5 feet in height and were growing very slowly. There had been some damage to the spruce by gall aphids. A light thinning was made in the canopy in this year and again in 1927.

In 1932 it was apparent that there was still too much cover and all the large trees in the overwood were removed, leaving a young stand of oaks averaging somewhat taller than the spruce and fir to come along with the latter. About half of the balsam still remained. These averaged slightly smaller than the spruce.

The response of the spruce and fir to the heavy cutting in 1932 was much the same as for spruce on Plot 10. Those trees which had not become malformed responded very well during the succeeding five years, while those which had been badly suppressed prior to thinning showed very little increase in growth. The foliage of the balsam fir had become somewhat yellow, indicating that the exposure was too great for this species.

From a comparison of the development of spruce on Plots 8a, 8b, 10, 13, 42, 43 and 69 it seems apparent:

1. That this species will fail on light sandy soil unless there is some cover for the first 10 years while it is becoming established.
2. That high cover is more satisfactory than low cover.
3. That the cover must be rather heavily thinned, beginning at about the tenth year after planting, otherwise the trees will become flat-topped and will respond very slowly to releasing.

Most of the balsam fir was uprooted by the hurricane but the damage to the spruce was negligible.

Future operations on the plot will be for the purpose of bringing through a mixed stand of spruce and hardwoods with the former making up over 50 percent of the mixture.

PLOT 14. White Pine. Area about 1.2 acres.

Planted in the spring of 1908 with Scotch pine three-year transplants in furrows plowed through the brush, of which no description was given but which was presumably small. The spacing was 5 by 6 feet. The brush was cut on part of the plot in 1910 and on the balance in 1913. There were further cleaning operations in 1919 and 1924, the last being final. Several large chestnut and pitch pine trees were either cut or girdled.

The development of the stand was not satisfactory. Early losses reduced the number of trees and those that survived were crooked and

limby with large spreading crowns. This was probably caused by severe competition during early life, by snow damage and, perhaps, by lack of adaptation to the site of the trees used.

In 1932 there were not over a dozen trees of satisfactory form on the plot, and a heavy thinning was made with the object of creating a thin high cover, averaging 40 feet in height, for underplanting with spruce two years later. This operation was not carried out.

An examination in the fall of 1937 showed that an excellent seedling of white pine had come in on two-thirds of the plot adjacent to Plot 15, following the heavy seed crop on that plot in 1934. Scotch pine needle litter apparently forms a very favorable medium for the germination of white pine seed, much better than white pine litter. This may be due to the coarseness of needles which allows the seed to filter through to mineral soil.

The revised objective, as decided upon in 1937, was to bring through the natural white pine seedlings under a thin high cover, removing the latter about 1950-55. However, the hurricane of 1938 completely destroyed the Scotch pine. It was expected that the heavy salvage cuttings in conifers would result in an almost total loss of the seedlings from Pales weevil. Observations made in October 1940 showed that these escaped serious injury. They were from 8 to 24 inches tall and had excellent color. Much hardwood volunteer growth has come in since the 1932 cutting, and periodic weedings will be needed to release the white pine seedlings.

PLOT 15. White Pine. Area about .8 acre.

Planted in May 1906 with white pine three-year seedlings, spaced 5 by 6 feet. No record was made of the cover at the time of planting. It seems probable, however, that there was some cover because it was necessary to clean the plot of brush in 1913. This is further borne out by the fact that there was little or no weevil injury below 7 feet, indicating that there had been very good protection from this insect. Losses up to 1912 had amounted to only 10 percent. A second release cutting was made in 1919 and a final in 1924. (Plate I, Figure b, shows white pine in 1937 after thinning and pruning.)

By 1923 the trees had reached an average diameter of 3.5 inches and a height of 19 feet. The amount of weeviling had been slight, the recovery from injury very good and differentiation into crown classes quite marked.

In 1932 a medium-heavy crown thinning was made, reducing the number of trees to approximately half those planted. About 10 cords of wood were removed. This was made up largely of weeviled dominant trees.

In 1934, 235 trees were pruned to a height of 6 to 8 feet and two years later this pruning was extended to 25 feet on the above trees and about 70 others. Of those pruned, half had perfectly straight

boles and the rest were satisfactory crop trees. Only about 5 percent of the limbs removed were alive. The work was done with curved saws, using a ladder where necessary.

By 1937 most of the debris from the 1932 cutting had disappeared. Numerous small seedlings originating from the 1934 seed crop had come in but will probably not survive because of the density of the parent stand.

Table 5 shows the volume on the plot, as of September 1934 and October 1938. The latter figures do not include 266 cubic feet of wood per acre from trees blown down by the hurricane.

TABLE 5. VOLUME OF WHITE PINE ON PLOT 15, SEPTEMBER 1934 AND OCTOBER 1938

Volume in 1934				Volume in 1938		
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	16.6	12	— ²	16.6	4	— ²
2	22.6	59	15.3	22.6	28	6.0
3	26.7	59	38.9	26.7	33	15.2
4	30.0	124	162.5	30.3	87	110.9
5	32.5	194	427.5	33.3	146	297.4
6	34.4	176	582.0	35.8	172	560.1
7	35.8	127	591.0	37.7	158	688.9
8	36.7	58	360.0	39.1	82	485.3
9	37.5	22	171.5	40.3	41	306.5
10	38.2	1	9.8	41.1	13	126.0
11	...	...	....	41.9	1	12.8
Total	...	832	2,358.5	...	765	2,609.1

¹ From Chart I, Bulletin 427, of this Station.

² Below Limits of Volume Table.

Future operations on this plot will consist of thinnings from time to time as needed.

PLOT 16. White Pine—Red Pine—Japanese Red Pine. Area about 3.7 acres.

Planted with white pine, red pine and Japanese red pine, spaced 5 by 5 feet. The plot was later divided up into sections a, b and c, according to the arrangement of the three species. Several cleanings were carried out between 1919 and 1926.

Section a. (across the road from Plot 15). White pine and red pine were planted in alternate rows in 1915 and 1916. The survival of red pine on this section has been about 90 percent, of white pine about 35 percent. Losses in the latter were particularly heavy (about 85 percent in the 12 rows nearest Plot 15) and here about half the red pine was removed in 1932. The object of this cutting was to create a number of small openings in which white pine was to be planted. The red pine was to have been removed after serving as a protective cover for the younger white pine. The white pine planting was not

made. For practical purposes much of the stand here is red pine with a 10 by 10-foot spacing, together with some white pine which is of good form but somewhat smaller than the other species. On the balance of this section, losses in the white pine amounted to about 40 percent.

In 1936 the white pine averaged 18 feet tall and 3 inches D. B. H., and the red pine 22 feet tall and 5 inches D. B. H. At the present time the former is of good form with small side branches and is comparatively free of weevil damage. However, it is rapidly being forced into a subordinate position by the red pine.

Since it is desired to maintain the section as a mixed stand, a cutting operation will be necessary in the near future. This will be confined almost wholly to the red pine with the objective of maintaining from 25 to 40 percent of white pine in the mixture. In preparation for this, some 200 trees per acre of both species were pruned in the winter of 1940 and 1941. Pruning was to a height of about 8 feet and was done with a saw. The limbs were cut close to the bole and an attempt was made to wound the collar so as to hasten the development of callous growth.

Section b. (middle of Plot 16). Planted in 1916 with white pine and Japanese red pine in alternate rows. The latter species has developed somewhat better than elsewhere on the tract but is still of too poor form to be considered in forest planting. It averages nearly as tall as the white pine (15 to 20 feet) but, in competition with the latter, it has lost a large amount of crown and will, without doubt, be killed out entirely in a few years.

The survival of white pine has been much higher than on Section a. The trees have larger limbs and weevil injury has been more marked than on Section a. There are, however, sufficient good trees to make an acceptable final stand. From present appearances the white pine will take complete possession of the ground and will not need thinning for another 10 years or more. A pruning operation on some 200 white pines per acre will be carried out in the winter of 1941-42 in the same manner as for Section a. The hurricane damage on Sections a and b was negligible.

Section c. (west side of Plot 16). Planted to red pine in 1916. This was a very good stand of red pine and, until it was severely damaged by the hurricane in 1938, had grown considerably faster than older stands of this species at Rainbow. Losses for the first 20 years amounted to less than 5 percent.

A permanent sample plot was laid out in this section in 1930 and remeasured in 1936. This sample plot was one of a series of 24 plots laid out in red pine stands in Connecticut for the study of site. The average annual increment in total peeled volume per acre for the six-year period was 150 cubic feet. (For a record of the volume increment on two other sample plots in the series, see Plot 22.)

The portion of the section left standing after the hurricane will be pruned and thinned when necessary. No plans have yet been made for that part of the section which was destroyed.

PLOT 17. Administration. Area about .9 acre.

This plot was originally occupied by a nursery formerly operated in connection with the tract. At present, a portion is used for a parking area and the balance is occupied by tree growth which originated as follows:

1. The white pine at the west end was planted in 1915. Failures were rather heavy, and the stand is irregular and much too open. Weevil injury has been severe. It should be possible to increase the density and obtain a satisfactory stand by natural seeding. The hurricane did little damage to this planting.

2. The red pine planting near the parking area was established by planting in 1920. It was used between 1924 and 1930 for an experiment in the removal of living branches. Some of the pruning was quite drastic and the trees have not yet recovered. The results of this work were published in the *Journal of Forestry*, Volume XXIX, page 541, 1931. Many of the trees in this experiment were destroyed by the hurricane.

3. The portion of the plot between growths 1 and 2 is occupied by a miscellany of trees left in the old nursery rows at the time of abandonment in 1913. This section received no treatment until 1932 when a cutting was made to relieve competition and give the better individuals a chance. On account of the excessive competition over a long period, it is impossible to make comparisons of the growth of the several species. On this area are to be found Douglas fir, red pine, ash, red and white oaks, Norway and sugar maples, European larch and black locust. Damage by the hurricane on this section was negligible except on red pine, which was completely destroyed.

No experiments are planned for this plot but thinnings will be made as needed to keep the trees in good growing condition.

PLOT 18. White Spruce. Area about .7 acre.

Planted in the spring of 1924 with white spruce two-year seedlings, spaced 8 by 8 feet under a medium dense cover of pitch pine 8 to 10 inches in diameter and smaller trees of aspen, gray and paper birch, etc. Losses during the first summer amounted to 10 percent but by 1930 an additional 80 percent had died, probably because of too small stock and excessive competition. The pitch pine was removed in the winter of 1930-31 but the hardwood understory was so dense that few of the surviving spruce have made satisfactory growth.

This is the only experiment with white spruce at Rainbow and little has been learned about its development on poor soil.

PLOT 19. Japanese Red Pine. Area about 1.2 acres.

Planted in May 1910 with Japanese red pine two-year seedlings, spaced 6 by 6 feet. A 50 percent loss was replaced the following year

with three-year transplants of the same species. While no mention was made of the cover at the time of planting, there must have been a fairly dense thicket of young gray birch on the ground, because this species was overtopping the pine in 1919 when it was heavily cut to release the latter. All hardwoods were removed in 1923.

Up to the time the hardwoods were removed, competition had resulted in the production of single stems by the planted species. Development was not satisfactory, however, because the trees had made very little diameter growth and were crooked. After the competition was removed, the trees developed branched tops above 10 feet, which was approximately the height of the trees at the time of releasing.

This species is not considered satisfactory for forest planting on sandy soils. If grown in the open, it develops multiple stems. Slow growth in diameter is characteristic under all conditions and, in competition with hardwoods, the trees become very spindling.

The experiment with Japanese red pine on Plot 19 has been abandoned and the land will be used for other purposes.

PLOTS 20 and 21. White Pine and Scotch Pine. Area about 2.6 acres.

Planted in the spring of 1904 with white pine and hardwoods, spaced 5 by 5 feet as follows: solid rows of hardwoods alternating with mixed rows of white pine and two species of hardwoods. Hence, the pine formed one-third of the mixed rows and one-sixth of the entire stand. The only difference between Plots 20 and 21 was in the species of hardwoods used. These were beech and red oak on Plot 20 and sugar maple and red oak on Plot 21.

By 1910 a high percentage of the hardwoods had died and, in May of that year, the solid hardwood rows were replanted with white pine four-year transplants and the mixed rows with Scotch pine three-year seedlings. The 5 by 5-foot spacing was maintained, the surviving hardwoods being ignored in the replanting. The plantation now consisted of about 65 percent white pine and 35 percent Scotch pine. Both plots were cleaned of encroaching hardwoods in 1919.

By 1923 the Scotch pine had reached a height of 17 feet and the white pine of 10 feet (trees from the 1904 planting excepted) and had overtopped much of the latter species. Losses in both species had amounted to 30 percent. There had been very little weevil injury to the younger white pine.

In 1932 a heavy cutting was made, removing mostly Scotch pine but also some of the poorly formed 1904 white pine. This was done to determine whether the 1910 white pine, 90 percent of which had been suppressed, would recover and develop normally. In 1934 about 250 trees of each species were pruned to a height of 6 to 8 feet and, in 1936, 129 trees, mostly Scotch pine, were pruned to a height of 15 to 25 feet, removing 5 to 10 percent live branches. A light thinning was

made to further release some promising white pines. The pruning was done with curved saws, using ladders when necessary.

Damage from the hurricane of 1938 necessitated the removal of practically all the remaining Scotch pine together with some white pine, the latter being chiefly slender trees under 3 inches in diameter.

The present stand is extremely irregular and composed mainly of white pine from 3 to 40 feet in height, together with a few large Scotch pine and hardwoods. There are numerous openings up to 50 feet across and in these there is a considerable quantity of white and Scotch pine reproduction up to 1 foot in height.

The results of the thinnings and salvage cuttings are disappointing. The tops of many of the younger white pines had become malformed through suppression and these have responded very little to releasing. The balance, some 30 percent, had grown slowly but normally, prior to the cutting. These have responded quite well to thinning.

These plots are very good examples of the small amount of weevil injury that occurs when white pine is grown in a subordinate position in the stand. They are also examples of leaving the protective cover over white pine for too long a period. In this case, the first thinning to release the white pine should probably have been made 10 years earlier.

These plots will be maintained in approximately their present condition to determine: (1) if the malformed white pine will eventually recover and assume normal form and growth, and (2) if the reproduction already on the ground, or that which may come in, will restock the openings and further increase the irregularity of the stand.

PLOT 22. Red Pine and White Pine. Area about .8 acre.

Planted in May 1902 with red pine four-year transplants, spaced $4\frac{1}{2}$ by 5 feet, except for a small area at the north end where about 100 white pine were planted (probably at about the same time). Fail places were filled in the spring of 1904. The ground was entirely free of woody vegetation at the time of planting (See Plate Ia).

In 1923 the crowns had closed and branches were dead for 7 feet above ground. Losses for both species had been quite small. The red pine averaged 20 feet tall and 3.8 inches D. B. H., and the white pine 16 feet tall and 2.4 inches D. B. H. The latter showed very little weevil injury, probably because this species formed a small block of trees which was entirely surrounded by taller trees.

In 1928 the portion of the plot occupied by red pine was given a very light thinning and, in the fall of that year, seven permanent sample plots of one-fortieth acre each were laid out for the purpose of studying the growth of the trees in response to treatment of the litter. All slash from the thinning was removed before the plots

were established. Following are the litter treatments for the several plots:

- a. Accumulated needle litter raked off at the time of establishment and current litter raked off annually.
- b. Same as a, with ground limestone added.
- c. Accumulated needle litter left intact (check plot).
- d. Same as c, with ground limestone added.
- e. Accumulated needle litter burned in place at the time of establishment and current litter burned in place annually.
- f. Same as e, with ground limestone added.
- g. The litter raked annually from Plots a and b is distributed evenly over Plot g.

The height and D. B. H. of every tree on the seven plots is measured very carefully at intervals of three to five years. Comprehensive soil analyses are made periodically. At the time of remeasurement in 1934, the plots were again given a very light thinning, and 10 to 12 trees on each plot were selected for special consideration in future cuttings. It is planned to continue these experiments for a considerable period of years and to report results obtained from time to time. To date no outstanding differences are apparent on the several plots.

In May 1930, a one-tenth acre permanent sample plot was laid out in red pine near the north end of Plot 22. This is one of a series of 24 plots established throughout the State for the purpose of studying the growth of red pine in relation to site quality. This sample plot had the lowest site index (height at age 15 years from seed) found on any of the 24 plots. The average annual increment in total peeled volume per acre for the period 1930 to 1936 was 97 cubic feet. The average annual increment per acre for the same period on the plot in the series with the highest site index was 272 cubic feet or nearly three times as much (See Plot 16.).

The one-tenth acre sample plot was thinned in the fall of 1936. At that time the dead limbs on all trees on Plot 22 were pruned off, using curved saws and ladders. The resulting debris was removed from the seven plots used for litter experiments.

Damage from the 1938 hurricane was slight. A few trees which were in the litter study plots were partially uprooted. These were pulled back into position and anchored. Future operations on Plot 22 will be for the purpose of furthering the experiments described above.

PLOT 23. Scotch Pine. Area about .6 acre.

Most of this plot was planted in April 1902 with Scotch pine three-year seedlings, (Plate I, Figure a), spaced 4 by 5 feet. The remainder was planted in the spring of 1904 with Scotch pine two-year transplants. At the same time, losses in the 1902 planting, amounting to 8 percent, were replaced. In 1905 the trees were 31 in-

ches tall, and in 1911 the stand had closed and shaded out herbaceous vegetation. There was no woody vegetation on the ground at the time of planting.

Permanent sample plot 100, .89 acre in area, was established in 1919 after having been thinned. No record was kept of the material removed but it is estimated that some 600 trees per acre, with a volume totaling 400 cubic feet, were removed. The plot was again thinned and remeasured in 1924, thinned a third time in 1929, and remeasured in 1934 and 1938. Table 6 shows the volume of wood on the plot at the time of the operations described.

TABLE 6. VOLUME OF SCOTCH PINE ON PERMANENT SAMPLE PLOT 100, 1919-38

After thinning spring 1919				Removed spring 1924			After thinning spring 1924		
D.B.H.	Height	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.
ins.	ft.								
1	12.2	11	— ²	..	..	..	..	..	..
2	17.4	101	22.2	20.4	45	11.2	..	..	..
3	21.8	876	499.3	25.4	338	216.3	25.4	123	78.7
4	25.4	348	386.3	28.7	146	181.0	28.7	483	598.9
5	28.2	34	62.9	31.4	11	22.9	31.4	180	374.4
6	...	...	....	...	..	..	33.4	44	136.4
Total	...	1,370	970.7	...	540	431.4	..	830	1,188.4

Removed 1929				At remeasurement fall 1934			At remeasurement fall 1938		
D.B.H. ins.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.
3	29.4	11	8.1	...	..	....	...	..	....
4	33.2	90	127.8	38.6	67	109.9	34.0	45	65.2
5	36.3	90	217.8	42.8	135	382.0	40.2	101	267.6
6	38.7	11	40.5	44.5	213	873.3	45.6	202	848.4
7	...	..	....	46.5	112	644.0	49.8	124	756.4
8	...	..	....	48.0	90	679.5	52.1	112	918.4
9	...	..	....	49.4	11	107.2	53.0	45	468.0
Total	....	202	394.2	...	628	2,795.9	...	629	3,324.0

¹ From Chart I, Bulletin 413, of this Station.

² Below Limits of Volume Table.

Permanent sample plot number 99, .080 acre in area, was laid out in 1920 to serve as a check against plot 100. The plot was remeasured in 1924, 1934 and 1938. Table 7 shows the volume of wood on the plot when established and at the time of the three remeasurements.

In 1932 that portion of Plot 23 not included in the two permanent sample plots was thinned. In 1936 all trees in the plot were pruned

TABLE 7. VOLUME OF SCOTCH PINE ON PERMANENT SAMPLE PLOT 99, 1920-38

At establishment spring 1920				At remeasurement spring 1924			At remeasurement fall 1934			At remeasurement fall 1938		
D.B.H. ins.	Hgt. ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	14.5	199	— ²	14.8	87	— ²	...	...	...	...	...	...
2	21.3	547	136.7	22.1	348	90.5	24.5	25	7.2	...	...	...
3	24.0	846	516.1	26.7	672	450.2	32.6	62	50.8	35.4	25	22.0
4	25.0	423	461.1	29.1	497	626.2	39.2	211	354.5	41.8	112	199.4
5	25.8	62	103.5	30.3	274	548.0	43.2	274	780.9	46.0	225	686.2
6	...	...	...	...	...	...	44.8	187	774.2	48.2	188	827.2
7	...	...	...	...	...	...	45.8	124	694.4	49.3	125	756.2
8	...	...	...	...	...	...	46.2	25	163.7	50.2	88	695.2
9	...	...	...	...	...	...	...	...	...	50.8	12	120.0
Total ..	2,077	1,217.4	...	...	1,878	1,714.9	...	908	2,825.7	...	775	3,306.2

¹ From Chart I, Bulletin 413, of this Station.² Below Limits of Volume Table.

to a height of 25 feet removing no live limbs. Curved saws and ladders were used.

The hurricane of 1938 almost completely destroyed the stand on this plot. Two small groups of trees, one at either end, remain. Brush remaining after the salvage cutting was piled and burned. In the spring of 1940 the plot, with the exception of a small area at the south end, was planted with white pine five-year transplants. During the three years since the salvage cutting, a large amount of woody and herbaceous growth has come in on the plot. Pin cherry is the most common tree species present.

PLOT 24. Red Pine—White Pine—Austrian Pine. Area about .4 acre.

The major portion of the plot was planted in April 1902 with red pine four-year seedlings, spaced 4½ by 5 feet. In July of the same year, 100 Austrian pine four-year seedlings were planted 4 by 5 feet at the south end of the plot. In the spring of 1905, planting of the plot was completed with the setting of 50 white pine at the north end. During the first year losses in the red pine amounted to 2 percent, and in the Austrian pine to 17 percent. The Austrian pine grew faster during the first three years but in 1906 both species averaged 29 inches tall. By 1923 the Austrian pine had again taken the lead and averaged 2 feet taller than the red pine. It is interesting to note that the red pine on this plot has made consistently better growth in height and diameter than that on Plot 22, which is the same age and planted under almost identically the same conditions.

Permanent sample plot 98, .092 acre in area, was established in 1920. It was remeasured in 1925, 1934 and 1938, and thinned in 1925 and 1936. Table 8 shows the volume of wood on the plot at the time of the operations described.

TABLE 8. VOLUME OF RED PINE ON PERMANENT SAMPLE PLOT 98, 1920-38

At establishment spring 1920				Removed spring 1925			After thinning spring 1925		
D.B.H. ins.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	10.0	11	— ²	16.5	22	— ²	...	...	....
2	14.5	261	49.7	20.8	98	24.5	...	...	....
3	17.8	892	419.0	23.8	349	209.4	23.8	196	117.6
4	20.7	554	497.5	26.0	262	293.5	26.0	608	682.0
5	23.3	45	72.9	28.0	54	98.3	28.0	185	337.0
6	...	...	....	...	...	....	29.7	11	29.7
Total	...	1,763	1,039.1	...	785	625.7	...	1,000	1,166.3

At remeasurement fall 1934				Removed fall 1936			At remeasurement fall 1938		
D.B.H. ins.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.
3	31.2	44	34.3	31.0	22	16.8	...	...	....
4	34.7	228	337.5	35.3	141	211.5	34.7	33	48.0
5	37.3	413	1,024.0	38.7	131	338.0	39.7	207	549.0
6	39.3	293	1,059.0	41.3	11	41.8	43.0	380	1,498.0
7	40.9	22	111.0	...	...	....	45.1	76	422.0
Total	...	1,000	2,565.8	...	305	608.1	...	696	2,517.0

¹ From Chart I, Bulletin 413, of this Station.² Below Limits of Volume Table.

As a check against the sample plot described above, permanent sample plot 91, .0919 acre in area, was laid out in 1925. It was measured in 1934 and again in 1938. The volume of wood on the plot as of these dates is shown in Table 9.

TABLE 9. VOLUME OF RED PINE ON PERMANENT SAMPLE PLOT 91, 1934 and 1938

At remeasurement fall 1934				At remeasurement fall 1938		
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	15.0	22	— ²	...	...	....
2	22.5	272	70.7	20.4	120	28.8
3	28.0	457	319.0	28.1	358	254.0
4	31.9	685	938.0	34.2	630	927.0
5	34.2	326	743.0	37.8	358	907.0
6	35.5	33	108.5	39.8	98	363.0
7	...	...	....	40.3	11	55.0
Total	...	1,795	2,179.2	...	1,575	2,534.8

¹ From Chart I, Bulletin 413, of this Station.² Below Limits of Volume Table.

In 1932 the Austrian pine and red pine not included in the permanent sample plots was thinned, and in 1936 the dead limbs on all trees on Plot 24 (white pine excepted) were removed. This pruning extended to a height of 20 to 25 feet and was done with curved saws and ladders.

All the white pine and most of the red pine on this plot were cut, following damage by the 1938 hurricane (Plate III, Figure b). The cleared area was planted with white pine five-year transplants in the spring of 1940. This planting is an extension of that mentioned under Plot 23. The natural vegetation which has come in is similar to that on the latter plot.

A small block of Austrian pine and red pine at the south end of the plot was not seriously damaged and will be maintained for further observation.

PLOT 25. White Pine. Area about .8 acre.

Most of this plot was planted, in the spring of 1902, with white pine seedlings 8 to 18 inches tall, collected in Granby. Failures were replaced in 1903 with white and green ash nursery seedlings and basswood and tulip collected seedlings. In 1904 and 1905 fail places and a strip at the north end, which was not planted in 1902, were planted with collected white pine seedlings. The spacing used was $4\frac{1}{2}$ by $5\frac{1}{2}$ feet. Losses were moderately heavy in the white pine, which averaged 42 inches tall in 1906. By 1907 the hardwoods had either died or were growing so slowly that they had no influence on the stand. In 1911 the stand was reported as irregular due to failures, differences in stock and weevil injury.

In 1923 the trees averaged 23 feet tall and 4 inches D. B. H. and the stand had closed. Weevil damage had been slight. The stand was still irregular and the crowns of the trees longer and narrower than in stands originating from nursery stock.

In 1932 crown differentiation had become further developed and the stand had much the appearance of a natural stand which had seeded in over a period of years. In 1934 the trees averaged 28 feet tall and 5.3 inches D. B. H.

In 1929 the south end of the plot was lightly thinned and, on the thinned area, a series of small plots was laid out for a study of litter treatment. These plots were similar to those laid out in red pine on Plot 22.

In 1936 the portion of the plot not used for litter experiments was thinned, and 275 trees were pruned to a height of 15 to 20 feet, removing few live limbs. Pruning was also carried out on the series of small plots, from which the cut branches were removed.

The hurricane of 1938 destroyed most of the stand, except for a group of trees at either end of the plot, and made it necessary to aban-

don the several experiments. Since the salvage cutting, much woody and herbaceous vegetation has come in. There is almost no white pine reproduction. No plans have yet been made for the future use of the plot.

PLOT 26. White Pine. Area about 1.2 acres.

Planted in April 1903 with white pine two-year transplants, spaced 4 by 4 feet at the north end, 5 by 5 feet in the middle, and 6 by 6 feet at the south end. Failures were replaced in the spring of 1904 with three-year white pine transplants. In 1907 losses had amounted to 2½ percent and the trees averaged 34 inches tall.

Table 10, made up from measurements and counts taken in the fall of 1938, portrays the condition of the trees on the three spacings before the hurricane.

TABLE 10. CONDITION OF WHITE PINES IN PLOT 26 PRIOR TO HURRICANE

At remeasurement fall 1938	Spacing, feet		
	4 by 4	5 by 5	6 by 6
Average D. B. H., inches	4.0	5.2	5.9
Average height, feet	27	30	34
Length of green crown, feet	11	11	12
Age from seed, years	38	38	38
Number living trees per acre, 1938	1,810	1,340	1,030
Number trees planted per acre, 1903	2,580	1,850	1,290
Number of deaths per acre, 1903-38	770	510	260
Losses as a percent of number planted	30	26	20
Total peeled volume ¹ per acre, cu. ft. (approximate)	2,140	- 2,935	3,250

¹ From Chart I, Bulletin 427, of this Station.

The plot has received no silvicultural treatment, except a salvage cutting after the hurricane. Damage was comparatively light in the 4 by 4 and 5 by 5-foot spacings and heavy in the 6 by 6-foot spacing, rendering the last unsuitable for further comparisons of spacing, although there is a fairly open stand on the ground.

The plot will be maintained for future comparisons of 4 by 4 and 5 by 5-foot spacings.

PLOT 27. White Pine. Area about 1.0 acre.

Planted in the spring of 1904 with chestnut one-year seedlings and white pine two-year seedlings, spaced 6 by 6 feet, two rows of chestnut alternating with two rows of pine. By 1907 losses in the pine had amounted to 25 percent, and in the chestnut to 40 percent. By 1910 the latter had practically all died and was replaced with white pine four-year transplants, thus forming a two-aged stand of white pine.

By 1923, the 1904 trees had closed but the 1910 trees had not. The former were 20 feet tall and had begun to suppress the latter, which were only 14 feet tall. The older trees had been badly damaged by

weevil and had wide, deep crowns and large side branches. The younger had been only slightly damaged by weevil and had narrow crowns and small side branches.

In 1932 a thinning was made, removing most of the 1904 planting but leaving a few trees to maintain the irregularity of the stand. This thinning had been delayed too long. Many of the 1910 trees had been suppressed so long that the crowns were malformed and did not respond to releasing. Those which were of good form at the time of cutting have responded well but are too few in number to make an acceptable stand. There was very little disintegration of slash during the five years following cutting, owing to the openness of the stand. Some seedlings from the 1934 seed crop have come up in the openings.

In 1936, 200 trees were pruned to about half their height (10-15 feet), 5 percent of the branches removed being alive. The work was done with curved saws and ladders. Hurricane damage was negligible. Future work on the plot will be for the purpose of developing a white pine stand which is uneven-aged by groups. This will be done by encouraging natural seeding to fill in the open spaces.

PLOT 28. White Pine. Area about 1.6 acres.

Planted in April and May 1902 with white pine three and four-year seedlings and four-year transplants, spaced 4 by 5 feet and 4½ by 5 feet. Tulip seedlings (135) were planted at the same time but these had all disappeared by 1906. Failures in the white pine during the first two years amounted to less than 5 percent. These were replaced in 1904 and 1905. In 1907, 6 percent of the trees had been weevilled and the infested tops were removed.

Permanent sample plot 97, one-eighth acre in area, was laid out and measured in 1920. It was remeasured and thinned in 1925 and remeasured again in 1934. Table 11 gives the volume of wood on the plot as of the above dates.

TABLE 11. VOLUME OF WHITE PINE ON PERMANENT SAMPLE PLOT 97, 1920-34

At establishment spring 1920				After thinning spring 1925			Removed spring 1925		At remeasurement fall 1934		
D.B.H. ins.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. Trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	10.0	112	— ²	...	...	...	...	...	...	...	...
2	13.5	520	78.1	...	...	...	72	13.7	...	...	...
3	16.0	816	318.5	19.4	168	80.7	176	84.5	29.8	24	17.8
4	17.7	488	377.0	20.4	360	317.0	224	197.0	31.7	48	65.7
5	18.7	24	30.0	20.9	208	291.0	88	123.0	32.3	176	385.0
6	...	..	....	21.3	8	16.4	32	65.5	33.0	256	832.5
7	...	..	....	...	...	...	...	...	33.3	160	698.0
8	...	..	....	...	...	...	...	...	33.7	64	361.6
9	...	..	....	...	...	...	...	...	34.0	16	115.2
Total	...	1,960	803.6	...	744	705.1	592	483.7	...	744	2,475.8

¹ From Chart I, Bulletin 427, of this Station.

² Below Limits of Volume Table.

Permanent sample plot 92, one-eighth acre in area, was established as a check against Plot 97. It was measured in 1934. Table 12 gives the volume of wood on the plot as of the above dates.

TABLE 12. VOLUME OF WHITE PINE ON PERMANENT SAMPLE PLOT 92, 1925 and 1934

At establishment spring 1925				At remeasurement fall 1934		
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	11.1	168	— ²	...	...	...
2	15.4	512	86.9	19.7	8	1.8
3	18.6	744	342.0	23.5	408	237.0
4	21.0	432	388.0	26.2	400	452.0
5	22.3	72	108.0	28.2	472	896.0
6	23.0	8	17.6	29.6	136	385.0
7	...	...	....	30.6	16	64.0
8	...	...	....	31.5	16	84.8
Total	...	1,936	942.5		1,456	2,120.6

¹ From Chart I, Bulletin 427, of this Station.

² Below Limits of Volume Table.

The sample plots were abandoned, after remeasurement in 1934, because of an injury to the crowns (see Plate II), which occurred between 1920 and 1925 but which did not become apparent until a number of years later. Nearly all the trees on the plot, except for a small area at the south end, were severely injured. The exact cause is not known, but it is believed to have been caused by a heavy blanket of ice or snow being caught on the canopy. The nature of the injury was a malformation of the crowns from which there has been no recovery after more than 15 years (Plate II, Figure b).

In 1936 about .6 of an acre at the south end of the plot, on which there had been little or no crown injury, was thinned and 150 trees pruned to a height of 15 to 25 feet. Not over 10 percent of the limbs removed were alive. The balance of the plot was used for the initiation of experiments in establishing a stand of white pine by natural seeding. Seven openings of various sizes and shapes were cut clear and the slash removed. In 1937 a replicated series of treatments was performed on the soil, the litter and such vegetation as had come in since the cutting. This was done in order to determine, if possible, what constitutes a favorable seed bed for white pine.

The 1938 hurricane felled a considerable number of trees on the plot. Many of the openings cleared in 1936 were enlarged. The stakes used in marking the litter experiments were destroyed and it seems probable that the entire series will have to be abandoned. Much woody and herbaceous vegetation has come in since the stand was opened up. There is some white pine reproduction but not, as yet, in sufficient amount for satisfactory stocking.

PLOT 29. White Pine. Area about 2.2 acres.

Planted in September 1907 with white pine three-year transplants, spaced 5 by 5 feet. As a test of fall planting, the experiment was a success, resulting in over 75 percent survival.

By 1923 the trees averaged 15 feet in height and were just closing. Weevil damage had been heavy. Differentiation into crown classes had been quite marked and the stand was quite irregular in appearance. This may have been due to early competition with brush which was removed in 1919.

In 1932 a medium heavy thinning was made, taking out about 10 cords of wood. The trees removed were mostly large-crowned dominants which had been badly weeviled.

In 1934, 195 trees were pruned to a height of 6 to 8 feet. In 1936, 235 trees, including those pruned two years earlier, were pruned to a height of 10 feet, 10 percent of the branches removed being alive.

On account of the irregularity of the crowns and the openings caused by the removal of wide-crowned, badly weevilled dominant trees, the general appearance of the stand is not as good as that of some plots on which the trees have developed more evenly. However, the crowns of the trees are relatively long and narrow and there is a wide variation in height and in crown classes. It is believed that this is a better silvicultural condition for stands of this age than where the trees are all of nearly equal size.

Future management of the plot will be for the purpose of maintaining the present irregularity. This will be done by making crown thinnings from time to time.

The plot was measured after the hurricane of 1938 which damaged about 140 cubic feet per acre of material, chiefly in the lower diameter classes. The volume of wood on the plot is shown in Table 13.

TABLE 13. VOLUME OF WHITE PINE ON PLOT 29, AUGUST 1938

D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	12.7	29	— ²
2	19.4	95	21.8
3	23.7	119	69.0
4	26.7	117	135.8
5	29.3	142	284.0
6	30.9	120	354.0
7	32.3	73	310.0
8	33.4	32	179.5
9	34.2	6	43.2
10	35.0	1	9.1
Total	...	734	1,406.4

¹ From Chart I, Bulletin 427, of this Station.

² Below Limits of Volume Table.

PLOT 30. Jack Pine. Area about .3 acre.

Planted with a 5 by 5-foot spacing in May 1908 with jack pine seedlings, 1 to 2 feet tall, from Michigan. During the first four years, growth was quite slow and losses amounted to about 50 percent.

Under these conditions, development was not satisfactory. The trees tended to produce crooked boles and long, heavy side branches. The species produces seed abundantly and, in a number of places on or adjacent to the plot, there are seedlings which have been subjected to rather severe competition. These are straight-boled with small side branches and of much better appearance than the parent trees. It would appear from this that a comparatively narrow spacing is needed for best development. This is borne out by conditions on Plot 46, where Jack pine was used as a filler and developed better form than on Plot 30.

While no tests have been made to determine the mechanical properties of the wood of planted Jack pine, the amount of summer wood appears to be greater than for red or Scotch pine grown under similar conditions. If its wood should prove to have superior strength properties, there may be a place for planted Jack pine in the East for the production of heavy duty posts, for which the wood of the other conifers commonly planted is too weak.

The stand was completely destroyed by the hurricane of 1938. Measurements taken during salvage operations show that the trees averaged 4.6 inches D. B. H. by 32 feet in height. No plans have as yet been made for further experiments on the plot.

PLOT 31. Scotch Pine. Area about .3 acre.

Planted in April 1903 with green ash one-year seedlings, spaced 10 by 10 feet. In the spring of 1904, Scotch pine two-year seedlings were planted alternately with the ash in the ash rows, and 5 feet apart in solid rows between the ash rows, thus making the spacing for the plot 5 by 5 feet. Much of the ash died during the first three years and had entirely disappeared by 1923. The death of the ash increased the growing space for the pine by about 25 percent. Losses in the pine amounted to about 5 percent. There was some injury to the crowns around 1924. This is believed to have been caused by ice or snow and may have happened at the same time as the injury to the white pine crowns on Plot 28. The recovery from the injury was, however, much better on the Scotch than on the white pine.

The stand was given a heavy thinning in 1932, removing about 5 cords of wood and, in 1934, 90 trees were pruned to a height of 8 feet. Practically all the trees on the plot were snapped off during the hurricane of 1938.

The plot was measured in the fall of 1934 and again at the time of salvage operations in 1938. Table 14 gives the volume of wood on the plot as of these two years.

TABLE 14. VOLUME OF SCOTCH PINE ON PLOT 31, 1934 and 1938

Fall of 1934				Fall of 1938		
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.
3	28.5	12	8.6	...	...	...
4	34.2	42	61.8	34.2	21	30.9
5	38.0	67	167.5	38.2	45	114.7
6	40.2	133	492.0	41.7	67	260.0
7	41.9	157	814.0	44.0	142	774.0
8	43.1	82	559.0	45.4	100	720.0
9	44.0	9	78.7	46.0	70	637.0
10	44.5	9	96.3	46.3	18	198.0
11	45.0	...	...	46.7	6	79.2
12	45.1	3	43.8	46.9	...	...
13	45.2	3	48.6	47.0	3	50.1
Total	...	517	2,370.3	...	472 ²	2,863.9

¹ From Chart 1, Bulletin 413, of this Station, extrapolated.

² Fifteen trees (45 per acre) were removed between 1934 and 1938.

This was a very good stand of Scotch pine. The crowns were much heavier than on the thinned portion of Plot 23, where cuttings were begun in 1919 in a stand of approximately the same age but spaced much more closely. It was, however, in better condition than the unthinned portion of Plot 23 where competition had been too keen.

Assuming that the strain of Scotch pine is suited to the site, the best procedure in handling this species on sandy soils seems to be to plant closely and thin early. Under these conditions early natural pruning is good and the crowns can be kept in satisfactory shape. If planted too closely and left unthinned, the trees lose too much crown. With wide spacing, there is a tendency to produce spreading crowns and large side branches. This is what happened on Plots 20 and 21 where originally Scotch pine formed only about 35 percent of the stand but soon assumed the lead over the white pine which it suppressed. No plans have been made for further experiments on the plot.

PLOT 32. Spruce Underplanting. Area about 1.5 acres.

Planting was begun on this plot in 1902, between which year and 1927 the history of the plot is a succession of fires and replanting. The cover, which was old pitch pine and younger hardwoods, varied from almost pure pitch pine at the south end to scattered pitch pine over a younger hardwood stand at the north end near the highway. This cover was quite dense and, while it was thinned several times, there was still so much shade that most of the spruce developed flat tops or was killed.

The principal species used in the various plantings was Norway spruce but there are a number of trees of other species of spruce near the south end of the plot.

The plot is a good example of what may happen when spruce is planted under too dense cover and not released early enough. On a small area at the south end of the plot where the cover was not too dense, the trees have done quite well. These will be maintained. The experiment with spruce on the balance of the plot will be terminated and the land used for other purposes.

PLOT 33. White Pine Underplanting. Area about 1.5 acres.

Planted in May 1905 with white pine two-year seedlings under a medium-dense shade of pitch pine 30 feet tall. (Although not mentioned, it seems probable that there was some advance growth of small hardwoods under the pitch pine at the time of planting). The pitch pine was thinned in 1913 and most of the larger trees were removed in 1925. Others were cut in the winter of 1931-32.

In 1923, and again in 1926, fires burned over about half the plot near the highway killing most of the planted trees. A part of the burned area was planted to Norway spruce in 1926 and 1927, but competition with hardwood sprouts, has killed out or suppressed most of this species to a point where there is little use in attempting to release them. This section of the plot is a very good example of the behavior of spruce in competition with low cover, which not only competes strongly with the spruce but affords it no protection while it is getting established.

The balance of the plot, amounting to about 50 percent of its area, which was either unburned or burned over very lightly, is occupied by a very irregular stand of white pine. Losses have been fairly heavy and some trees have been malformed by too severe competition. However, considering the section still occupied by white pine as a whole, this species is in excellent condition. In 1936 the trees averaged 25 feet in height and 6 inches D. B. H. Weevil injury has been in inverse ratio to the amount of cover but, on the whole, has been slight and recovery from it very good. The crowns of the trees are narrow and deep, and side branches quite small. In many ways the development of white pine on this plot resembles that of natural white pine stands under similar conditions. A thin high canopy of pitch pine appears to be one of the best natural covers for planted white pine, offering the latter ample protection against weevil attack without seriously interfering with growth.

Future operations on this plot will be pruning and thinning to bring through 200 carefully selected white pine trees per acre. The burned section of the plot will be used for other experiments. The plot suffered only minor damage during the hurricane of 1938.

PLOT 34. Scotch Pine and White Pine. Area about .9 acre.

Planted in May 1911 with mountain pine (*P. montana*) three-year seedlings and Scotch pine four-year transplants in alternate rows, spaced 6 by 6 feet. Losses in the mountain pine (which proved to be

of the Mugho variety) were very heavy during the first two years, and the rows occupied by it were replanted in the spring of 1913 with white pine four-year transplants. The plot was cleaned of brush in 1923.

In that year, only about 5 percent of the mountain pine was alive. Losses in the other two species had been small. The Scotch pine was 11 feet tall and the white pine 6 feet. Cuttings to favor the latter should have begun about this time. They were, however, delayed until 1932 when a very heavy thinning was made in the Scotch pine to favor the white pine. The former had grown very fast and produced large spreading crowns, completely suppressing the white pine. There had been almost no weevil injury to the latter and comparatively little malformation of the tops. Growth, however, had been very slow. The crowns of the trees were very narrow, the side branches small and the boles very slender.

In 1934, 112 white pine and 66 Scotch pine were pruned to a height of 6 to 8 feet. At this time the Scotch pine averaged 29 feet tall and 5.8 inches D. B. H., and the white pine, 15 feet tall and 2.0 inches D. B. H. In 1936, 374 trees of both species, including those pruned in 1934, were further pruned, the Scotch pine to 10 to 15 feet and the white pine to 5 to 10 feet. The work was done with curved saws and ladders.

This plot is similar in many respects to Plots 20 and 21, although suppression of the white pine had progressed further on Plot 34 than on the other. All three plots are examples of the fact that, when the two species are grown together, the Scotch pine, having the faster rate of growth, assumes dominance at an early age. Under these conditions it is of rather poor form, limby with wide crowns. It affords protection against weevil injury to the white pine but it quickly suppresses the latter. Comparatively little damage was done by the hurricane.

Plot 34 will be maintained in approximately its present two-storied condition to determine the rate of recovery of white pine which had been suppressed for ten years before releasing.

PLOT 35. White Pine and Scotch Pine. Area about 2 acres.

Planted in the fall of 1902 and in the spring of 1903 with white oak (seed spotted three acorns to a hole), chestnut one-year seedlings and white pine two-year seedlings, spaced $4\frac{1}{2}$ by 5 feet. The planting was mixed by small groups with three to ten trees of each species forming a unit. The three species were about equally represented. Losses in the white pine were replaced with white pine three-year transplants in the spring of 1904.

By 1911 most of the hardwoods had failed and were replaced with Scotch pine three-year transplants. The stand was now about two-thirds Scotch pine and one-third white pine, the latter being in small groups surrounded by the former.

In 1923 the white pine averaged 15 feet tall and 3.5 inches D. B. H. and the Scotch pine 13 feet tall and 3.2 inches D. B. H. The stand had not quite closed. The white pine was very limby and had been severely weeviled. Losses had been small for both species.

By 1932 the Scotch pine had almost caught up to the white pine and by 1934 had surpassed it. The measurements for the two species in that year were Scotch pine 29 feet and white pine 27 feet in height; Scotch pine 5 inches and white pine 5.6 inches D. B. H. In 1932 a medium heavy thinning was made in which the groups of white pine were favored. At the same time, 197 white and 274 Scotch pines were pruned to a height of 6 to 8 feet. In 1936, 300 trees of both species were pruned to a height of 20 feet on the west half of the plot. Curved saws and ladders were used.

It is interesting to note that, with a handicap of eight years, the Scotch pine caught up to the white pine in about 20 years. Another interesting thing is the change in the white pine crowns as crowding by the Scotch pine increased. During the first 15 years, they were broad with large side branches; during the second 15 years they became narrower with smaller side branches. Approximately 25 percent of the trees on the plot were damaged by the hurricane of 1938 and had to be salvaged. Of those removed approximately 75 percent were Scotch pine. Prior to the storm the stand was made up of 45 percent Scotch pine and 55 percent white pine. After the storm the ratio was 35 percent of the former and 65 percent of the latter (Plate III, Figure a). The plot will be maintained with approximately its present composition and arrangement to determine the results of mixing the two species by groups.

PLOT 36. White Pine and Scotch Pine. Area about .9 acre.

Planted in April 1903 with white pine two-year transplants and wild seedlings of sugar maple, spaced 6 by 6 feet and alternating in the row. In 1904 losses were replaced with the same species. In 1906 the maple averaged 5 inches tall and the pine 29 inches. In 1908 the former was replaced with Scotch pine two-year and three-year seedlings. By 1913 the maple had disappeared entirely.

In 1923 it was apparent that the Scotch pine would eventually suppress the white pine and, in order to record the development of the two species, permanent sample plot 93, one-quarter acre in area, was established. In 1928 this plot was heavily thinned to favor the white pine by removing nearly half the volume of the Scotch pine (Plate IV, Figure b). The plot was remeasured again in 1939.

Table 15, shows the volume of wood on the plot, as of the dates mentioned above. The figures for 1939 include salvage material removed.

TABLE 15. VOLUME OF WHITE AND SCOTCH PINES ON PLOT 36, 1923-39

At establishment, spring 1923						
White pine				Scotch pine		
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ² peeled vol. per acre cu. ft.
1	10.3	120	— ³	11.4	56	— ³
2	13.7	168	25.7	15.5	76	15.2
3	15.9	188	73.3	17.7	140	65.8
4	17.3	108	81.0	19.4	164	142.8
5	18.1	60	73.2	20.3	64	88.5
6	18.9	4	7.3	...	...	....
Total	....	648	260.5	....	500	312.3

At remeasurement, spring 1928										
White pine					Scotch pine					
After thinning				Removed in thinning		After thinning			Removed in thinning	
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ² peeled vol. per acre cu. ft.	No. trees per acre	Total ² peeled vol. per acre cu. ft.
1	11.2	52	— ³	8	— ³	11.8	20	— ³	4	— ³
2	15.6	108	19.5	4	.7	16.6	44	9.2	4	.8
3	18.3	128	57.6	12	5.4	19.8	60	30.6	24	12.2
4	20.5	128	112.5	4	3.5	22.3	100	98.0	36	35.3
5	22.5	64	96.0	....	....	24.5	80	127.0	72	114.3
6	24.6	36	85.0	....	....	26.0	12	28.8	36	86.4
7	26.3	4	13.8	....	....	27.3	....	....	8	27.0
Total	....	520	384.4	28	9.6	....	316	293.6	184	276.0

At remeasurement, spring 1939						
White pine				Scotch pine		
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ² peeled vol. per acre cu. ft.
1	13.7	24	— ³	....	....	....
2	20.5	76	17.5	20.7	4	1.0
3	25.1	52	32.2	26.3	32	20.5
4	28.4	92	114.1	30.6	32	42.3
5	31.0	124	262.0	33.7	44	99.0
6	33.3	76	243.0	36.1	80	268.0
7	35.3	24	111.5	38.2	48	225.5
8	37.3	24	151.0	40.0	24	153.5
9	....	....	....	41.7	4	33.0
Total	....	492	931.3	....	268	842.8

¹ From Chart I, Bulletin 427, of this Station.² From Chart I, Bulletin 413, of this Station.³ Below Limits of Volume Table.

As a check against the sample plot described above, permanent sample Plot 88, one-quarter acre in area, was established in 1928. It

was remeasured in 1939. Table 16 shows the volume of wood on the plot as of these dates. The figures for 1939 include salvage materials removed after the hurricane.

TABLE 16. VOLUME OF WHITE AND SCOTCH PINES ON PERMANENT SAMPLE PLOT 88, 1928 and 1939

At establishment, spring of 1928						
White pine				Scotch pine		
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ² peeled vol. per acre cu. ft.
1	10.3	100	— ³	11.2	4	— ³
2	14.6	240	40.8	15.8	56	11.2
3	18.0	180	81.0	19.5	144	73.4
4	19.8	76	64.6	22.4	120	117.6
5	20.9	20	28.0	24.6	172	275.0
6	....	....	...	26.5	48	117.5
7	....	....	...	28.3	....	....
8	....	....	...	30.0	4	18.7
Total	....	616	214.4	....	548	613.4

At remeasurement, spring 1939						
White pine				Scotch pine		
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ² peeled vol. per acre cu. ft.
1	13.5	40	— ³	...	...	...
2	20.6	172	39.6	21.2	8	2.0
3	25.8	160	102.5	27.7	52	36.4
4	29.4	84	107.5	32.1	96	132.5
5	31.7	48	103.0	35.0	84	196.5
6	33.1	20	63.0	37.3	100	346.0
7	....	...	....	38.8	100	480.0
8	....	...	....	40.3	32	204.5
9	...	...	....	41.5	8	66.0
10	....	...	....	42.5	4	40.8
Total	....	524	415.6	...	484	1,504.7

¹ From Chart I, Bulletin 427, of this Station.

² From Chart I, Bulletin 413, of this Station.

³ Below Limits of Volume Table.

The hurricane of 1938 did considerable damage, particularly to the Scotch pine (Plate III, Figure a), and it may be necessary to abandon one or both of the permanent sample plots.

PLOT. 37. White Pine and Scotch Pine. Area about 1.0 acre.

Planted in April 1903 with white pine two-year transplants and sugar maple wild seedlings, spaced 6 by 6 feet. Solid rows of maple alternated with mixed rows of maple and pine. Failures were replaced with white pine three-year seedlings and maple nursery seedlings in May 1904.

In 1910 and 1911 the maple, which had died, was replaced with Scotch pine two-year seedlings and three-year transplants. The stand was now composed of about 25 percent white pine and 75 percent Scotch pine.

In 1923 the Scotch pine averaged 16 feet tall and the white pine, 12 feet. Both species were 2.2 inches D. B. H. The stand was just about to close. The white pine showed little evidence of weevil injury.

In 1932 a thinning was made to relieve competition among the Scotch pines, ignoring all but the very best individuals of white pine. The thinning was delayed too long with the result that the Scotch pine had slender boles and too short crowns (Plate IV, Figure a). At this time the Scotch pine averaged 32 feet tall and 5.5 inches D. B. H. In 1936, 200 trees of both species, including 190 which had been pruned to a height of 6 to 8 feet in 1934, were pruned to a height of 20 feet. Curved saws and ladders were used and only 5 percent of the limbs removed were alive.

It is interesting to compare this plot with plot 35, where, with the same handicap, it took the Scotch pine about 20 years to outgrow the white pine. On Plot 37, it took only about 10 years. The reason for this seems to be that there was a long stagnation period after planting for the white pine and a short one for the Scotch pine.

The hurricane of 1938 damaged much of the Scotch pine and the stand is now very open. The plot will probably be used for another experiment.

PLOT 38. White Pine and Douglas Fir. Area about .4 acre.

Planted in April 1903, together with Plot 39, with white pine, Douglas fir and four species of hardwoods, spaced 5 by 5 feet. The white pine was planted 10 by 10 feet on both plots and all the fir was planted on Plot 38. Since the hardwoods were a complete failure, it is impossible to tell just how the several species were arranged. It seems probable, however, that the pine and fir were planted in about equal numbers. The plot was cleaned of birch in 1924.

In 1923 the fir averaged 10 feet tall and 1.3 inches D. B. H., and the pine 18 feet tall and 4.6 inches D. B. H. There was a variation in the height of the fir from 2 to 19 feet. There had been little weevil injury to the pine but the crowns were very broad and the branches large. The leaders of many of the firs had been killed back, probably by frost. Due partly to crowding and partly to its natural habit of growth, the crowns of the fir were quite narrow.

In 1932 the relative condition of the two species was much the same as in 1923. In 1934 the pine averaged 28 feet tall and 6.8 inches D. B. H., and the fir 22 feet tall and 3.7 inches D. B. H. There was still much variation in the height of the latter. The pine was very limby and wide crowned.

Douglas fir is a tolerant species and, unless absolutely overtopped, will force its way upward. An effort was made in 1936 to favor the better fir by removing some of the large white pines. The results were not satisfactory because the fir, being slender-boled, was bent over by snow and ice when its support was removed. The cutting should have been made when the stand was much younger. The species apparently has little value for the reforestation of very sandy soils. The hurricane of 1938 destroyed most of the fir but did little damage to the white pine.

PLOT 39. White Pine. Area about .7 acre.

Planted in April 1903 with white pine and a miscellany of hardwoods with a spacing of 5 by 5 feet. The hardwoods died leaving the pine spaced 10 by 10 feet. In 1924 the plot was cleaned of brush and, at the same time, the branches on the trees on the south half of the plot were removed to a height of 8 feet with an axe and the material sold.

In 1923 the crowns were just closing. The trees averaged 17 feet in height and 4.6 inches in diameter. Fifty percent of them had been weeviled. Crowns were wide, limbs large and boles crooked.

In 1934, 30 trees were pruned to a height of 6 to 8 feet. In 1936, 41 trees, including those pruned two years before, were pruned to a height of 10 to 15 feet. Pruning was done with curved saws and ladders.

There was comparatively little hurricane damage on the plot. Table 17 shows the volume of wood as of the fall of 1939, after removing 155 cubic feet per acre of salvage material.

TABLE 17. VOLUME OF WHITE PINE ON PLOT 39, FALL OF 1939

D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	17.2	13	— ²
2	22.2	4	1.0
3	25.7	14	9.0
4	28.3	19	23.4
5	30.5	24	50.2
6	32.3	33	102.2
7	33.7	40	176.0
8	35.0	43	254.0
9	36.1	47	359.0
10	37.2	33	319.0
11	38.2	16	189.0
12	39.0	4	57.2
13	39.8	3	51.0
Total	...	293	1,591.0

¹ From Chart I, Bulletin 427, of this Station.

² Below Limits of Volume Table.

The growth made by individual trees on the plot is appreciably higher than on plots with narrower spacing. The total yield, however, is much lower and the quality of material produced is very poor. The figures in the above table may be compared with those under Plot 4 (spaced 12 by 12 feet), Plot 12 (spaced 5 by 5 feet), and Plot 15 (spaced 5 by 6 feet). These plots were planted between 1902 and 1906.

Due chiefly to severe weeviling less than 15 percent of the trees, or 40 per acre, have acceptable form, i. e., straight boles and narrow crowns. The number of good trees per acre needed at this age to produce a good final stand should probably be around 200 per acre.

The plot will be maintained in approximately its present condition to determine the effect of pruning large branches, and for comparison of the volume growth with that on other plots with closer spacing. Since the trees have large crowns and are, therefore, in condition to produce good seed crops, an effort will be made to replace the present stand eventually with a young stand of white pine by natural seedling.

PLOT 40. White Pine. Area about .9 acre.

In 1903 this plot was planted to red oak which was almost a complete failure. In 1924 red pine two-year seedlings were planted 8 by 8 feet under a dense cover of gray birch averaging 10 feet tall. Losses were heavy and the trees that survived were removed to make room for the white pine planting described below. In 1929 the stand was chiefly gray birch, 10 to 30 feet tall, with scattered trees of red oak. This was very heavily thinned and, in the spring of 1930, the plot was underplanted with three-year white pine seedlings, spaced 6 by 6 feet. The stock was poor and the losses heavy. These were replaced in the spring of 1931 with four-year transplants (3-1) of the same species.

The plot was turned over to the Entomology Department of the Station for a study of weevil injury to white pine under a gray birch cover. Cuttings were made in the birch as follows:

- a. On one-third of the plot at the south end the birch was cut clear and cuttings have been made annually to keep down the sprouts, leaving the pine entirely unshaded.
- b. On one-third of the plot, north of "a", the birch was cut clear and allowed to sprout. From time to time, cuttings are made to free the tops of the pines only.
- c. On the north third of the plot the birch is being kept in approximately the same condition as it was after the heavy cutting in 1929.

All white pines on the plot are tagged, and growth in height and weevil injury are recorded annually. It is planned to carry on the experiment for a number of years and to report the results when it is closed out.

Note on Plots 41, 42, 43, 44 and 46.

The land occupied by these plots, aggregating about 11 acres, was planted as a unit in April 1906 with white pine and Norway spruce two-year seedlings and sugar maple three-year seedlings, spaced 5 by 6 feet. On most of the area, pine and spruce were alternated by rows. On the west side, however, maple was planted with pine in alternate rows.

About 1911 the area was divided up into Plots 41, 42, 43, 44 and 46. Plots 41 and 46, which lay east of a roadway through the planting, had little or no cover at the time the trees were set. The balance of the area bore a cover of pitch pine and hardwoods 30 to 40 feet tall which varied both in composition and density. This portion was divided into three very nearly equal parts and called Plots 42, 43 and 44. Plot 44 contained very little spruce. Plot 42 was separated from Plot 43 on the basis of a proposed plan for handling the cover, which was not followed.

In 1911 one acre of overwood was removed from Plot 42 and, between 1919 and 1930, the entire overwood was removed from Plots 42, 43 and 44.

In 1932 the entire area occupied by Plots 42, 43 and 44 was given a medium-heavy thinning, and at this time the boundaries of the three plots were rearranged. Plot 44, which is practically all pine, was reduced in width to about 160 feet. The balance of the area originally occupied by Plot 44 and that occupied by Plots 42 and 43, having a fairly uniform spruce and pine composition, was set off as a separate unit for future treatment and designated Plot 42-43.

The administrative road, (double dash line on map) running southeast to northwest across Plots 42-43 and Plot 44, was opened about 1925. Three administrative alleys, southwest to northeast, (single dash line on map) parallel to the long sides of Plot 42-43 divide this plot into four nearly equal parts. A fourth alley (solid line) forms the dividing line between Plots 42-43 and 44.

PLOT 41. White Pine and Norway Spruce (see note above). Area about .2 acre.

This plot contains only four rows of trees. Owing to its small size, it is being included with Plot 46 to the north, which it resembles quite closely. The hurricane destroyed about 50 trees nearly equally divided between the two species.

PLOT 42-43. White Pine and Norway Spruce (see note above). Area about 7.8 acres.

The effect of the cover on the planted stand was to hold back the pine more in proportion than the spruce, and to allow the latter to become well established. A comparison should be made between conditions on this plot and on Plot 69, where the two species were planted

in the open and where the pine quickly suppressed the spruce. Seventy Norway spruce on the east side were pruned to a height of 8 feet in 1929, using curved saws.

At the time of the thinning in 1932, the pine outnumbered the spruce about two to one and was crowding the latter severely. The cutting removed about 30 cords of wood, chiefly from badly weeviled, wide-topped pines.

A sample one-quarter acre tally taken in 1934 showed that there were 544 spruce and 432 pines per acre. The former averaged 25 feet tall and 3.4 inches D. B. H., and the latter 29 feet tall and 4.6 inches D. B. H. In maximum height the spruce was equal to the pine. In this year 458 pines (including some on Plot 44) and 165 spruce were pruned to a height of 6 to 8 feet and, in 1936, 2,000 trees of both species, including those pruned in 1929 and 1934, were pruned to a height of 15 feet on Plots 42-43 and 44. Curved saws and ladders were used. Only two whorls of live limbs were removed from the pines. The limbs cut from the spruce were practically all alive.

This plot is probably in as good condition silviculturally as any at Rainbow. Due to conditions already described, the stand is very irregular but there are plenty of well-shaped trees of both species to form an excellent mixed final stand. It is also one of the few instances on the tract where two species established in mixture appear compatible.

Damage from the hurricane was very slight. Some 80 trees, about equally divided between the two species, were blown down. Future operations on the plot will be for the purpose of developing a mixed stand of the two species. No further operations will be needed for several years.

PLOT 44. White Pine (see note above). Area about 2.1 acres.

The maple which was originally planted with the pine was a complete failure. It was replaced in 1910 and 1911 with white pine four-year and five-year transplants. Due to a long planting period and to the effect of the overwood, the stand is quite irregular. There is a small amount of Norway spruce on the north and east sides.

The thinning in 1932 removed about 7 cords of wood, mostly from wide-crowned, weeviled, dominant trees. The remaining stand contains an excellent assortment of well-formed trees to make up a final crop.

During the summer of 1938 a group of trees, about one-eighth acre in area, was discovered uprooted on the westerly side of the plot near Plot 45. It was found that the roots of the trees had been severely attacked by *Fomes annosus*. A study of root systems exposed by the hurricane showed that the disease was fairly widespread over the tract but at no place was the damage as severe as on Plot 44.

In general, damage by the hurricane on the plot was small. About 200 trees were injured but these were mostly scattered or in small groups.

Table 18 shows the volume of wood on the plot as of the fall of 1938 after damaged trees had been removed.

TABLE 18. VOLUME OF WHITE PINE ON PLOT 44, FALL OF 1938

White pine				Norway spruce		
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	12.8	19	— ²	9.0	2	— ²
2	19.8	58	14.5	15.9	6	1.1
3	24.2	77	46.2	21.1	8	4.2
4	27.5	91	108.4	25.7	3	3.4
5	29.8	81	164.5	30.2	1	2.0
6	31.5	56	171.0	33.8	..	..
7	33.1	54	232.5	36.9	1	4.8
8	34.4	38	220.0	...	..	....
9	35.6	14	105.0	...	..	....
10	36.8	9	85.5	...	..	....
Total	....	497	1,147.6	...	21	15.5

¹ From Chart I, Bulletin 427, of this Station.

² Below Limits of Volume Table.

Pruning and thinning operations will be carried out when needed in order to develop a quality stand of white pine.

PLOT 45. Miscellaneous Experiments. Area about 4.6 acres.

In 1910 the entire plot was planted to Corsican pine two-year seedlings, spaced 6 by 6 feet. Most of these died and were replaced in 1912 with mountain pine three-year transplants, spaced 6 by 6 feet. These proved to be Mugho pine and, between 1915 and 1925, were practically all removed and sold for ornamental purposes.

In 1927 planting was again resumed on the plot. At this time the area was occupied by a heterogeneous cover made up of gray birch, pitch pine, scrub oak and white pine volunteer growth. A few Corsican pines from the 1910 planting and a few Mugho pines from the 1912 planting, together with much Mugho reproduction, were also present. This cover varied greatly in density and in size of the trees.

In May 1927 about .7 acre, extending across the south end of the plot adjacent to Plot 16, was planted to Scotch pine. The soil on this section of the plot seems to be very poor. Losses in the Scotch pine have been heavy and growth quite slow.

In May 1930 a 50-foot strip along the north end of the plot adjacent to Plot 62 was planted with several varieties of chestnut for observations on their resistance to blight. Survival has been excellent but growth has been very slow.

In the spring of 1932 several plantings were established for the study of white pine weevil damage and control as follows:

a. One acre planted with red and white pine three-year transplants, spaced 6 by 6 feet. The two species were planted in groups of 36 trees each, the several groups arranged like the squares of a checkerboard.

b. One acre planted with white pine three-year transplants, spaced 4 by 4, 6 by 6, and 8 by 8 feet, the area divided equally among the three spacings.

c. One-quarter acre planted with white and red pine three-year transplants, spaced 6 by 6 feet, a solid row of pine alternating with a row of red and white pine mixed.

All white pine trees in these plantings are tagged. Measurements of growth and observations on weevil injury are made annually. Weedings are performed as needed. Results will be reported when the experiments are completed. Damage from the hurricane of 1938 was nil. Plot 45 will be managed for the furtherance of the experiments described above and to bring through a few of the best Corsican pine.

PLOT 46. White Pine—Norway Spruce—Jack Pine. Area about .7 acre.

Planted in April 1906 with white pine and Norway spruce two-year seedlings in alternate rows, spaced 5 by 6 feet (see note preceding Plot 41). It seems probable that there was little woody vegetation on the ground at the time of planting.

In May 1908 losses were replaced with Jack pine. Competing hardwoods were removed in 1919 and 1924.

In 1923 the white pine was 18 feet tall and 4.5 inches D. B. H.; the Jack pine 21 feet tall and 4 inches D. B. H. and the spruce 10 feet tall and 1.5 inches D. B. H. The stand had closed. There had been very little weevil injury to the white pine. A thinning should have been made at this time in order to save the spruce. The hurricane of 1938 blew down nearly all the trees on the plot.

The development of Jack pine on this plot was better than on Plot 30, where it was planted pure. The crowns were much narrower and the boles straighter than on the latter plot. With a handicap of two years it had exceeded the white pine in height growth in 15 years. From this it would seem that Jack pine might be a satisfactory species to use as a filler in stands up to five years older.

The spruce was represented largely as an understory of badly deformed trees. Its development had been intermediate between that on Plot 69, where it was entirely crowded out by white pine, and that on Plot 42-43 where it became firmly established and has done well.

The white pine was appreciably improved by being crowded by the Jack pine, and was of much better form than on Plot 69 where

it soon crowded the spruce out and grew with a wide spacing. No plans have as yet been made for further use of this plot.

PLOT 47. Mixed Conifers and Hardwoods. Area about 1.0 acre.

Planted in April 1903 with Douglas fir and a miscellany of hardwoods, mixed irregularly and spaced 5 by 5 feet. Hardwoods included basswood, tulip, chestnut and white and green ash. Most of these failed and, in May 1908 and again in May 1910, losses were replaced with Jack pine. Further losses were replaced with Norway spruce about 1916.

In 1923 the plot was about 25 percent stocked with Douglas fir, Jack pine and spruce, the first two species occupying five or six rows along the east side and the pine scattered over the balance of the plot, together with a few specimens of the planted and some volunteer hardwoods. The fir was very irregular in height but averaged 10 feet. The spruce was 3 feet tall. The Jack pine was 19 feet tall and 4.5 inches D. B. H. with wide crowns and crooked boles. In 1925 and 1926 several cords of birch were removed from the plot.

By 1932 the pine was badly crowding the fir and spruce and, in 1936, some of it was cut to free these two species. In 1934 a few trees each of fir, pine and spruce were pruned to a height of 8 feet with curved saws. Hurricane damage to this plot was severe, particularly to the Jack pine which was the principal species. The experiments described above will be abandoned and the land used for other purposes.

PLOT 48. Red Oak and White Pine. Area about .9 acre.

Planted in the spring of 1904 with red oak one-year seedlings and white pine two-year seedlings, spaced 6 by 6 feet, four rows of red oak alternating with two rows of white pine. By 1911 the white pine was beginning to overtop the oak, which had been damaged by rodents.

In 1923 the oaks which had not been damaged, amounting to about 50 percent of those planted, were 20 feet tall and 2.0 inches D. B. H. The balance had either died or were stunted and suppressed. Half of the white pine had been weeviled but side branches were small as a result of crowding by the oak. The stand had closed. A considerable amount of gray birch, which had come into the stand, was removed in 1926.

By 1932 the oak had overtopped practically all the pine. It had made fairly good growth, but was somewhat crooked and had not pruned itself very well. A thinning was made to favor the better oaks, removing about 2½ cords of wood.

The mixture of the two species, as described above, has not proved satisfactory. The white pine was ahead of the oak for the first 10 years and was consequently badly weeviled. Later, when the oak grew at a faster rate, it suppressed the pine. Comparisons should be made

with conditions on Plots 4 and 51 where the two species were used with somewhat different arrangement but without any better results.

There was little hurricane damage on the plot, that which occurred being confined almost wholly to white pine. The plot will be managed chiefly for red oak in the future in order to observe its behavior on poor soil. White pine of good form will be maintained wherever possible.

PLOT 49. Pitch Pine and White Pine. Area about .9 acre.

Planted in April 1903 with pitch pine two-year seedlings, spaced about 4 by 5 feet. Losses up to 1911 had amounted to only 6 percent.

In 1921 permanent sample plot 96 was laid out. It was divided into a thinned and an unthinned portion, each one-sixteenth acre in area, with a 30-foot isolation strip between. Table 19 shows the volume of wood on the two parts at the time of establishment in 1921 and at remeasurement in 1934.

TABLE 19. VOLUME OF PITCH PINE ON THINNED AND UNTHINNED PORTIONS OF SAMPLE PLOT 96, 1921 and 1934

Thinned Portion								
Before thinning spring 1921				Removed spring 1921		At remeasurement fall 1934		
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	8.5	208	— ²	160	— ²	...	...	—²
2	12.3	1,056	183.7	480	83.5	14.0	176	32.6
3	16.2	736	323.8	192	84.4	18.1	496	238.1
4	19.8	80	70.4	...	...	22.0	272	263.8
5	...	...	...	...	...	25.7	64	106.9
6	...	...	...	...	...	29.3	32	86.4
Total	...	2,080	577.9	832	167.9	...	1,040	727.8

Unthinned Portion								
At establishment spring 1921				At remeasurement fall 1934				
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre
1	7.5	288	— ²	11.5	80	— ²		
2	10.5	1,184	189.5	15.6	464	92.8		
3	13.4	576	224.6	18.7	736	360.6		
4	16.0	48	36.0	21.2	400	372.0		
5	...	...	...	23.3	80	122.4		
Total	...	2,096	450.1	...	1,760	947.8		

¹ From Chart I, Bulletin 413, of this Station.

² Below Limits of Volume Table.

The apparent lack of response to thinning was probably due to the loss by death of over 200 trees per acre on the thinned portion, subse-

quent to the thinning in 1921. The figures indicate the relatively slow growth of the species. They may be compared with those for white pine (Plot 28), red pine (Plot 24) and Scotch pine (Plot 23), which were planted about the same time and under approximately the same conditions.

The establishment of pitch pine by planting has not resulted in a satisfactory stand. Growth has been very slow, more so than where this species was established by direct seeding on Plot 3 and where it comes in of its own accord. It normally forms a considerable part of natural stands in the region and, while its growth is always relatively slow, it does attain reasonably acceptable form. The reasons for its behavior on Plot 49 are not entirely clear. There was some defoliation about 1921. About 1923 the crowns were injured in a manner similar to those of white pine on Plot 28 and probably by the same agency, namely, ice or snow. Recovery from injury has been good in both cases and it does not seem reasonable to attribute poor development to defoliation and crown injury. Pitch pine is intolerant and its behavior on this plot may have been due to stagnation. Losses, even after more than 30 years, had amounted to less than 25 percent in the unthinned portion of the stand, crowns were short and there was a comparatively small range of diameters and heights.

For more than 15 years white pine has been establishing itself on the plot by natural seeding. In 1936 it was decided to abandon the original experiment with pitch pine, including the permanent sample plots, and use the existing stand as a nurse crop for white pine. In that year the pitch pine canopy was reduced to about half density to favor white pine seedlings on the ground and to encourage further reproduction of this species.

A count of white pine reproduction in the fall of 1937 showed seedlings present in the following sizes and numbers:

Height of trees, ft.	Number of trees
0- $\frac{1}{2}$	1,789
$\frac{1}{2}$ -1	64
1-2	126
2-4	84
4-8	53
Over 8	22
Total on plot	2,138
Total per acre	2,375

Weevil injury to these trees was negligible.

This is about three times the number of white pine seedlings present under pitch pine on Plot 3, which was established by direct seeding at the same time as Plot 49. The difference is attributed to the presence on the latter of more pitch pine needle litter which seems to be an excellent medium for the germination of white pine seed. Hurricane damage on the plot was nil.

Future operations on Plot 49 will be for the purpose of raising a stand of white pine under a thin cover of pitch pine, which will be

reduced from time to time and removed when the white pine has reached a size where it is no longer subject to severe weevil attack.

PLOT 50. Red Oak. Area about .9 acre.

Planted in the spring of 1904 with red oak two-year seedlings, spaced 6 by 6 feet. In 1911, 90 percent of them were living but had been badly damaged by rodents. In 1923, 80 percent were still alive. Of these, 15 percent averaged 6 feet tall and the balance 3½ feet.

In 1936 a few trees at the south end of the plot had attained a height of 25 feet but were of poor form. A considerable number of others still persisted as an understory to birch, pitch pine and other species which had come in since planting.

The reasons for the very poor development of red oak on this plot are not clear. It was probably caused by planting on a sandy soil a species which reaches its best development on rich bottomlands. Competition with other species and damage by rodents were undoubtedly contributing factors. There was no hurricane damage to the plot. The experiment with red oak will be abandoned and the land used for other purposes.

PLOT 51. Red Oak and White Pine. Area about .9 acre.

Planted in the spring of 1904 with red oak one-year seedlings and white pine two-year seedlings, spaced 6 by 6 feet, two rows of red oak alternating with one row of white pine. In 1907 there was a high survival of both species and six years later both were recorded as having poor form.

In 1923 the pines had closed in the row, were badly weeviled and, at the south end of the plot, were being overtopped by the oak. At the north end of the plot the pine was suppressing the oak. For the plot as a whole, the pine averaged 17 feet tall, as compared with 19 feet for the oak.

By 1936 suppression had progressed so far that the south end was oak with an understory of pine and the north end, pine with an understory of oak. Neither species was of good form.

From the results obtained on Plots 4, 48 and 51, it is apparent that these two species cannot be successfully planted in intimate mixtures. Their habits are so different that one soon crowds the other into suppression. Which species gains ascendancy seems to be a matter of chance.

Hurricane damage on the plot was slight. It is planned to thin the plot in the near future to favor the best individuals of both species and to maintain a mixed stand if possible.

PLOT 52. White Pine and Japanese Red Pine. Area about .9 acre.

Planted in the spring of 1910 with Japanese red pine and white pine two-year seedlings, spaced 6 by 6 feet in alternate rows. Losses

in the Japanese red pine were heavy during the first three years and, in 1914, were replaced with white pine.

In 1923 the stand was cleaned of competing hardwoods. At this time both species were 7 feet in height and both had been badly weeviled, the white pine worse than the Japanese red pine. The former made up about 75 percent of the stand and the latter about 25 percent. The Japanese red pine exhibited the many-stemmed form which is characteristic of it when planted in the open.

By 1936 the Japanese red pine constituted only 15 percent of the stand, much of it being overtopped by the white pine. It is safe to say that very little of it will be alive in another 10 years. The 1910 white pine, which formed about half the stand, averaged 20 feet tall and 5 inches D. B. H. The trees were mostly dominant but had been severely injured by weevil and had large crowns. The 1914 white pine averaged 15 feet tall and 3 inches D. B. H. Most of the trees occupied a sub-dominant position, having narrow crowns and small side branches. These, together with some acceptable trees from the 1910 planting, will form an excellent nucleus for a final stand.

The plot is a very good example of keeping white pine in a sub-dominant position during the first 10 to 20 years. On trees grown in this manner, the crowns are narrow, side branches small and protection from weevil injury very high. The suggestion from this and other plots on the Rainbow tract is that white pine should be established in two-aged stands, the interval between plantings being about five years, and mixtures of the two age classes being by groups rather than by rows. The number of trees of the two age classes should be about equal.

Hurricane damage on the plot was very slight. Plot 52 will be managed to bring through the subdominant trees by removing the poorly formed dominants in thinnings. The first cutting will be needed in a very few years.

PLOT 53. White Pine. Area about .2 acre.

This plot was probably planted at the same time as Plot 33 but, unlike the latter, bore little or no cover at the time of planting. Early losses were heavy and the trees are wide-crowned and practically all have been badly weeviled. Owing to its small size, this plot will be handled for experimental work with Plot 54, which it now resembles more closely than it does Plot 33.

PLOT 54. White Pine and Scotch Pine. Area about .9 acre.

Planted in the spring of 1910 with white pine three-year transplants and Japanese black pine two-year seedlings, spaced 6 by 6 feet in alternate rows. The plot was cleaned of competing hardwoods in 1923. At this time the white pine was 7 feet tall and had been badly weeviled. Losses in it had amounted to 25 percent. Only 10 percent

of the Japanese black pine had survived. It had developed multiple stems and much of it was more or less procumbent.

In 1925 the rows occupied by Japanese black pine on the west side of the plot were planted with Scotch pine.

In 1936 no Japanese black pine was found. The Scotch pine averaged 5 feet in height and will be entirely crowded out in a few years by the white pine, which averaged 30 feet tall at this time. For practical purposes the white pine has grown with a 6 by 12 foot spacing, as the other planted species offered no competition.

There is a little pitch pine overwood on a small portion of the plot and, under this, the white pine has done quite well and is of good form. On the rest of the plot the spacing was too great and the white pine is wide-crowned and has been badly weeviled.

Hurricane damage was comparatively light on Plots 53 and 54. Most of it was confined to the northerly side of the plots and was fully as heavy in the pitch pine cover as in the planted species. There are enough good sub-dominant trees to form a fairly acceptable stand. A thinning will be made in the near future to favor these. Plot 53 will be handled with this plot in any future experimental work.

PLOT 55. White Pine. Area about .9 acre.

Planted in April 1903 with white pine two-year seedlings and collected beech seedlings, spaced 6 by 6 feet and alternating in the row. In the spring of 1904 failures were replaced with white pine three-year seedlings and beech nursery seedlings. In 1907 the pine averaged 25 inches tall and the beech 11 inches. By 1911 the latter had practically all died. Theoretically, this should have resulted in the pine being spaced $8\frac{1}{2}$ by $8\frac{1}{2}$ feet. Based on a count of the number of trees per acre, the spacing was found to be more nearly $7\frac{1}{2}$ by $7\frac{1}{2}$ feet.

In 1923 the crowns had just closed. The trees averaged 17 feet in height and 4.5 inches D. B. H. They were limby from wide spacing and 50 percent of them had been weeviled. In 1924 the branches below 8 feet on all trees in the south half of the plot were removed with an axe and sold.

Table 20 shows the volume of wood on the plot as of the fall of 1939. The only stem material ever removed from this plot was 295 cubic feet per acre of wood salvaged after the hurricane, which did relatively little damage. This salvage material is not included in the table.

This plot is something of an enigma, in that it is much better than wide-spaced stands of white pine usually are. For some reason, differentiation into crown classes took place at an early age and there are, consequently, a large number of trees in a subdominant position to make up the final stand. Wide spacing has delayed the need for

TABLE 20. VOLUME OF WHITE PINE ON PLOT 55, FALL OF 1939

D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	12.5	6	— ²
2	19.3	18	4.0
3	24.2	76	45.6
4	27.5	92	110.4
5	29.8	123	248.5
6	31.5	157	474.0
7	32.7	111	477.5
8	33.7	64	365.0
9	34.5	29	210.0
10	35.2	11	100.0
Total	...	687	2,035.0

¹ From Chart I, Bulletin 427, of this Station.² Below Limits of Volume Table.

thinnings, which will be started in the near future. At the time of cutting some 200 to 250 trees per acre will be pruned.

PLOT 56. White Pine and Scotch Pine. Area about 0.8 acre.

Planted in April 1903 with collected beech seedlings and white pine two-year seedlings, spaced 6 by 6 feet, a solid row of beech alternating with a row of beech and pine mixed. Losses were heavy during the first year and, in 1904, were replaced with beech nursery seedlings and white pine three-year transplants. By 1911 the beech had practically all died and was replaced by Scotch pine three-year transplants. The stand was then composed of about 25 percent white pine and 75 percent Scotch pine.

In 1923 the white pine averaged 17 feet tall and 4.5 inches D. B. H. and the Scotch pine, 16 feet tall and 3.0 inches D. B. H. Fifty percent of the former had been weeviled. The stand was just closing.

In 1932 a thinning was made removing 7 cords of wood. Such white pine as were of good form, amounting to about 10 percent of the stand, were favored. The balance was removed to favor Scotch pine which was generally of good form. This cutting was delayed about five years too long, resulting in too much shortening of the Scotch pine crowns.

The plot was measured in the fall of 1934. Table 21 shows the volume of the two species as of that date.

The hurricane of 1938 caused severe damage, especially to the Scotch pine. Table 21 shows the volume of both species as of the fall of 1939, after salvage of 309 cubic feet per acre of white pine and 484 cubic feet per acre of Scotch pine.

Further work with the current experiment will be based on the condition of the two species at the end of another five years.

TABLE 21. VOLUME OF WHITE AND SCOTCH PINES ON PLOT 56, 1934 and 1938

At remeasurement, fall 1934						
White pine				Scotch pine		
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ² peeled vol. per acre cu. ft.
1	13.8	5	— ³	15.8	2	— ³
2	18.6	29	6.1	22.9	24	6.5
3	22.3	35	19.2	27.3	46	31.6
4	25.8	54	61.0	30.8	86	114.4
5	28.8	62	122.1	33.8	129	291.5
6	31.2	49	147.0	35.9	86	286.4
7	33.0	35	151.2	37.4	31	142.6
8	34.2	19	109.2	38.6	4	24.6
9	34.9	1	7.4	...	...	...
10	35.3	5	45.5	...	...	...
11	35.5	2	22.0	...	...	...
Total	....	296	690.7	...	408	897.6

At remeasurement, fall 1939						
White pine				Scotch pine		
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ² peeled vol. per acre cu. ft.
2	17.8	15	3.1	...	..	....
3	24.9	16	9.8	31.2	14	10.9
4	28.9	24	30.2	34.4	25	36.7
5	31.7	24	51.4	36.9	50	123.0
6	33.9	30	97.5	39.2	35	126.7
7	36.0	32	150.4	41.4	41	209.1
8	37.8	19	120.6	43.5	16	110.4
9	39.6	11	91.3	45.5	9	81.0
10	41.3	4	42.4	...	..	....
11	42.8	2	26.4	...	..	....
12	44.5	5	81.5	...	..	....
Total	...	182	704.6	...	190	697.8

¹ From Chart I, Bulletin 427, of this Station.² From Chart I, Bulletin 413, of this Station.³ Below Limits of Volume Table.**PLOT 57. Red Pine.** Area about 1.0 acre.

Planted in the spring of 1924 with red pine two-year seedlings, spaced 8 by 8 feet. The land was cleared of all woody vegetation in the fall of 1923. At the end of the first year losses had amounted to less than 10 percent. A weeding operation was carried out in 1928 and another in 1932, when some of the best trees were pruned to a height of 3 feet with a pruning knife. A considerable number of volunteer seedlings of white pine, jack pine and Scotch pine had become established on the plot since planting, also some locust which was cut in weeding.

It became apparent in 1932 that there was a rather marked variation in the height growth of red pine on the plot. The best height growth was on the west side, near Plot 58, which is occupied by locust,

with a more or less well defined gradation in height growth to the poorest on the east side near Plot 56. An analysis of the soil showed that its *total nitrogen content* was quite uniform over the plot. Its *nitrifying power*, however, was much greater on the side toward the locust plot. It seems reasonable to assume that this is due to the effect of locust leaves blown in from Plot 58.

In 1934 a series of experiments in fertilizing and mulching individual trees was begun on the east side of the plot. It is too soon to report results of these experiments at this time. There was no damage by the hurricane. The plot will be maintained for the experiments described above and for others in pruning wide spaced red pine.

PLOT 58. Black Locust. Area about 1.0 acre.

Planted in April 1903 with black locust one-year seedlings, spaced 4 by 4, 5 by 5, and 6 by 6 feet. In 1906, 65 percent were alive, and in 1911 the trees were 15 to 25 feet tall.

In 1923 the average height was 35 feet and D. B. H., 6 inches. This was the largest size attained in 20 years by any species planted on the Rainbow tract. The trees, however, were very badly damaged by locust borer and were cut for cordwood at this time.

In 1925 the plot was planted to Scotch pine under a locust copice 10 feet tall. By 1932 the locust sprouts had reached a height of 25 feet and had killed out practically all the Scotch pine except a small patch at the south end of the plot. A considerable number of jack, white and Scotch pine and locust seedlings had come into some of the more open places. In the fall of 1932 the locust was again cut for cordwood.

By 1936 the second crop of locust sprouts had reached 15 to 20 feet in height. They appear to be of better form and to have been less severely attacked by borers than the original planting. There is a dense growth of high and low-vine blackberry under the locust. This is quite different from the vegetation which comes in after cuttings in pine stands on the area, where the species are mainly poke-berry and poison ivy. This is probably due to the enriching effect of locust leaf litter on Plot 58. Hurricane damage on the plot was negligible. Thinnings will be made in the locust from time to time to determine whether or not an acceptable stand can be raised from fast growing locust sprouts.

PLOT 59. White Pine. Area about 1 acre.

Planted in April 1903 and May 1904 with white pine two-year and three-year transplants and black birch seedlings. The spacing was 5 by 5 feet and the number of trees used was the same for both species. The arrangement of the two species at the time of planting is not definitely known but it seems probable that several different plans of mixing them were used. The birch had practically all died by 1906,

leaving the pine spaced irregularly but averaging 8 to 10 feet apart. Losses in the latter had amounted to less than 10 percent. In 1907 the trees were 40 inches tall.

In 1922, permanent sample plots 94 and 95, each one-quarter acre in area, were laid out and measured. The former was thinned and the latter left as a check. Both sample plots were remeasured in 1927 and 94 was thinned a second time. The plots were entirely destroyed by the hurricane in 1938. Tables 22 and 23 shows the stand per acre on the plots, as of the dates mentioned above.

TABLE 22. VOLUME OF WHITE PINE (THINNED) IN PERMANENT SAMPLE PLOT 94, 1922-38

Spring 1922					Spring 1927					Fall 1938		
After thinning				Removed	After thinning				Removed			
D.B.H.	Hgt	No.	Total ¹	No.	Total ¹	No.	Total ¹	No.	Total ¹	Height	No.	Total ¹
ins.	ft.	per	vol. per	per	vol. per	per	vol. per	per	vol. per	ft.	per	vol. per
		acre	acre	acre	acre	acre	acre	acre	acre		acre	acre
			cu. ft.		cu. ft.		cu. ft.		cu. ft.			cu. ft.
2	18.5	20	4.2	32	6.7	16.4	..	..	4	.7	..	..
3	21.0	44	22.7	84	43.3	21.2	4	2.1	12	6.2	..	..
4	22.5	192	186.2	88	85.4	24.8	8	8.6	52	56.2	35.8	4
5	23.5	220	347.6	24	37.9	27.4	72	133.9	40	74.4	38.3	8
6	24.4	152	355.7	4	9.4	29.4	96	272.6	32	90.9	40.2	48
7	25.3	4	13.2	..	..	31.2	152	623.2	32	131.2	41.7	40
8	..	..	..	..	..	32.6	52	286.0	8	44.0	42.8	94
9	..	..	..	..	..	..	..	..	..	..	43.9	94
10	..	..	..	..	..	..	..	..	..	..	44.8	64
11	..	..	..	..	..	..	..	..	..	..	45.7	28
Total	..	632	929.6	232	182.7	..	384	1,326.4	180	403.6	..	380
												3,081.4

¹ From Chart I, Bulletin 427, of this Station.

TABLE 23. VOLUME OF WHITE PINE (UNTHINNED) IN PERMANENT SAMPLE PLOT 95, 1922-38

Spring 1922				Spring 1927			Fall 1938		
D. B. H.	Height	No.	Total ¹	Height	No.	Total ¹	Height	No.	Total ¹
ins.	ft.	per	vol. per	ft.	per	vol. per	ft.	per	vol. per
		acre	acre		acre	acre		acre	acre
			cu. ft.			cu. ft.			cu. ft.
2	13.4	48	7.3	17.6	16	3.2	..	..	..
3	17.6	160	69.6	22.4	64	35.2	25.2	4	2.5
4	20.9	160	144.0	25.6	136	151.0	31.2	44	59.4
5	23.0	236	363.4	27.5	112	210.6	35.8	80	192.0
6	24.3	124	288.9	28.7	184	507.8	39.2	100	372.0
7	25.3	20	66.0	29.5	136	527.7	41.3	100	530.0
8	..	..	..	30.0	48	244.8	42.7	96	681.6
9	..	..	..	30.2	12	76.8	44.1	100	930.0
10	..	..	..	..	..	..	45.3	48	561.6
11	..	..	..	..	..	..	46.4	20	288.0
12	..	..	..	..	..	..	47.4	4	69.6
13	..	..	..	..	..	..	48.2	4	83.2
Total	..	748	939.2	..	708	1,757.1	..	600	3,769.9

The stand resulting from wide spacing on Plot 59 was poor. Weevil injury during early life was severe and many stems were badly malformed. The yield was better than that on Plot 39 with approximately the same spacing, but the quality of material was very low.

The plot will be used in a series of experiments to determine the effect of slash on the survival and growth of planted trees.

PLOT 60. White Pine. Area about 2.1 acres.

Planted in May 1905 with white pine, spaced 6 by 6 feet (see note under Plot 68). Competing hardwoods were removed in 1919.

In 1923 the trees averaged 19 feet tall and 4 inches D. B. H. Weeviled trees amounted to only 25 percent of the stand, which had closed.

In 1932 the plot was divided into three equal parts—a, b, and c—by north-south alleys to facilitate the hauling out of material from a thinning which was made in that year, removing 25 cords of wood on the three sections.

In 1935 a fire killed nearly all the trees on section a which lies across the road from Plot 59. All dead and badly fire-scarred trees were removed in 1936. In 1937 a series of experiments in soil preparation for natural seeding of white pine was laid out in anticipation of a heavy seed crop of this species in 1938. Few seedlings were found, probably because of the wide dispersal of seed by the hurricane which occurred as the cones were opening. The storm blew down most of the trees which remained after the fire.

The balance of Plot 60 (sections b and c), untouched by the fire, is occupied by a very excellent stand of white pine, much better than is usually obtained with this spacing on open land. There is an unusually high percentage of trees which have not been damaged by weevil or which have recovered rapidly from injury. Growth in height and diameter have been better than on other plots of the same age on the tract. The only apparent reason for the general excellence of the stand is a rather marked differentiation into crown classes which is so often lacking in planted white pine stands.

In 1936, 366 trees on sections b and c were pruned to a height of 15 to 20 feet. Only 5 percent of the branches removed were alive. Some of these trees had been pruned to a height of 6 to 7 feet in 1934. The tools used were curved saws and ladders. The hurricane of 1938 did very little damage on section c and moderate to heavy damage on section b, especially on the easterly side toward section a.

Table 24 shows the stand per acre on these two sections as of the fall of 1939 after 529 cubic feet per acre of salvage material had been removed.

TABLE 24. VOLUME OF WHITE PINE ON PLOT 60, FALL 1939

D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	12.8	5	— ²
2	20.5	23	5.3
3	26.8	51	33.7
4	31.6	50	69.0
5	34.7	59	137.0
6	36.8	67	234.5
7	38.5	73	365.0
8	39.8	49	328.0
9	41.1	21	182.5
10	42.2	4	43.2
11	43.0	1	13.2
Total	...	403	1,411.4

¹ From Chart I, Bulletin 427, of this Station.² Below Limits of Volume Table.

The plot will be thinned from time to time as needed.

PLOT 61. White Pine. Area about 2.2 acres.

Planted in the spring of 1913 with white pine five-year transplants spaced 5 by 6 feet. (Note: While the recorded spacing was 5 by 6 feet, actually it did not average 5 by 5 feet and many trees were only 3 feet apart.) The plot was cleaned of birch in 1919 and 1923. In the latter year the trees averaged 7 feet in height, and 40 percent of them had been injured by weevil.

In 1936 about 800 trees were pruned to a height of 8 feet using curved saws. This operation was followed by a thinning. No record was kept of the trees removed. Table 25 shows the volume of wood remaining on the plot as of the Fall of 1939 after 86 cubic feet per acre of hurricane-damaged material had been salvaged.

TABLE 25. VOLUME OF WHITE PINE ON PLOT 61, FALL OF 1939

D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	12.0	102	— ²
2	17.7	182	36.5
3	21.6	234	124.0
4	24.3	262	278.0
5	26.3	209	377.0
6	27.7	86	228.5
7	29.1	26	99.0
8	30.3	8	41.2
9	31.3	4	26.8
10	32.3	4	33.6
11	33.2	1	10.3
Total	...	1,118	1,254.9

¹ From Chart I, Bulletin 427, of this Station.² Below Limits of Volume Table.

This is a very excellent stand of white pine obtained by planting this species at the rate of about 2,000 trees per acre and thinning at 23 years. While the results are good, it is doubtful if such close spacing can be used without confiscating the investment at the start. The thinning of three years yielded a poor grade of fuelwood and, in practice, would not have paid for the operation.

The stand will be thinned from time to time as needed and the selected trees pruned to a greater height. No further cutting will be needed for at least five years.

PLOT 62. White Pine—Scotch Pine—Himalayan Pine. Area about 6 acres.

Planted in May 1907 with white pine two-year seedlings, spaced 5 by 5 feet. In 1919 the stand had just closed and some birch which had come in was removed. In 1922 a fire burned over the entire plot, killing the trees on about half the area and injuring many of those on the remainder.

In 1924 the dead white pines were removed and replaced with white and Scotch pine two-year seedlings, together with a little red pine. Losses were heavy and in 1929 these were replaced with Himalayan pine.

In 1934 the white pine from the 1907 planting averaged 29 feet in height and 6 inches D. B. H. The percentage of well-formed, sub-dominant trees was fairly high and in 1936 a medium heavy thinning was made to favor them. Two hundred trees per acre were pruned to a height of 15 to 20 feet, using curved saws and ladders. Five percent of the cut branches were alive. Fire scars had healed over on about 40 percent of the trees injured. On about 60 percent, only partial healing had taken place. No evidence of rot was found in the fire-scarred stumps at the time of thinning.

The heavily burned area, which was replanted in 1924 and 1929, is not in satisfactory condition. Losses in the planted trees have been heavy, and competition with birch and other volunteer species severe. The area is at present occupied by a thin stand of Scotch, white and red pines which average about 10 feet tall. A few Himalayan pine, none over 2 feet tall, still persist. About 50 percent of the white pines have been weeviled.

Hurricane damage in the older planting was light to moderate, except in the north central portion where it was heavy. There was little damage to the younger plantings. The area still occupied by the 1907 planting will be continued in its present form for further observations on growth and fire injury. Just what disposition will be made of the replanted area is undecided at the present time.

PLOT 63. Red Pine—White Pine—Scotch Pine. Area about 2.6 acres.

Planted in 1914 with white pine, spaced 12 by 12 feet. In 1915 red pine was planted between the white pines in one direction, reduc-

ing the spacing to 6 by 12 feet. In 1923 the plot was cleaned of competing birch, which was rather dense although of small size. In this year, both species averaged 5.5 feet in height. About half the white pine had been injured by weevil. In 1925 Scotch pine was planted 5 feet apart in solid rows between the mixed rows of white and red pine.

In 1936 the white pine averaged 18 feet tall and 4 inches D. B. H., and the red pine 22 feet tall and 5 inches D. B. H. The Scotch pine averaged only 4 feet tall, was very slender and had practically ceased growing in height. Only 20 percent of it was still alive. It had suffered competition, not only from the other pines but from dense young birch sprouts from the 1923 cleaning. In this year 297 white and 159 red pines were pruned to a height of 8 feet. Because of its dominant position, limbs on the red pine were large. Branches on the white pine were small and, in general, this species showed very good form. Recovery from weevil injury had been excellent.

Table 26 shows the stand per acre as of the fall of 1939, after 12 cubic feet per acre of white pine and 55 cubic feet per acre of red pine, which was damaged by the hurricane, had been removed.

TABLE 26. VOLUME OF RED, WHITE AND SCOTCH PINES ON PLOT 63, FALL 1939

White pine				Red pine		
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ² peeled vol. per acre cu. ft.
1	10.8	19	— ³	10.8	5	— ³
2	16.3	39	7.2	16.3	10	2.0
3	20.7	68	34.3	20.7	23	12.2
4	24.3	90	94.5	24.3	32	34.6
5	26.3	99	178.2	26.7	81	141.5
6	27.3	38	98.8	28.7	97	257.0
7	28.0	7	25.9	30.3	45	166.5
8	28.4	1	4.9	31.7	6	30.0
Total	...	361	443.8	...	299	643.8

¹ From Chart I, Bulletin 427, of this Station.

² From Chart I, Bulletin 413, of this Station.

³ Below Limits of Volume Table.

The plot will be maintained as a mixed stand of red and white pine with the two species about equally represented. A thinning will be made in the near future.

PLOT 64. Scotch Pine. Area about 1.3 acre.

Planted in May 1910 with Scotch pine two-year seedlings, planted 5 by 6 feet. Early losses, which were not replaced, increased the growing space to about 8 by 8 feet.

In 1923 the stand was open and the trees had large crowns and crooked boles. They averaged 15 feet tall and 2.5 inches D. B. H. In this year and in 1924, birch was removed and pitch pine girdled to free the Scotch pine.

The stand was completely destroyed by the hurricane of 1938. Table 27, assembled from measurements taken during salvage operations, shows the volume of wood as of the fall of 1938.

TABLE 27. VOLUME OF SCOTCH PINE ON PLOT 64, FALL 1938

Fall 1938			
D. B. H. ins.	Height ft	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	12.0	10	— ²
2	22.3	31	8.2
3	28.1	77	54.7
4	31.7	110	149.6
5	34.2	125	287.5
6	36.3	140	474.6
7	38.3	108	510.8
8	40.2	38	243.2
9	41.8	15	124.5
10	43.4	4	41.6
Total	...	658	1,894.7

¹ From Chart I, Bulletin 413, of this Station.

² Below Limits of Volume Table.

The development of this stand was not satisfactory. Under the conditions described, growth was good but the trees were wide-crowned and limby and the quality of material was low. Apparently this was the result of too wide spacing which allowed a few strong individuals to assume an early lead and crowd out or suppress the weaker trees.

The plot will be used for a series of experiments to determine the effect of slash on the survival and growth of planted trees.

PLOT 65. Red Pine. Area about .8 acre.

Planted about 1915 with red pine spaced 5 by 5 feet. There was probably an uneven cover of birch and pitch pine at the time of planting, since it was necessary to make a cleaning in 1923 when the red pine averaged 5 feet tall. Losses were small. A second cleaning was made in 1925.

Crown differentiation has been much more marked than is usual with planted red pine at this age. This condition is probably due to competition with birch and pitch pine which held some of the planted trees back. The advantage of this type of development is that the first thinning will be delayed longer than in more even stands.

The table below shows the stand per acre as of the fall of 1939, after 78 cubic feet per acre of material from hurricane-damaged trees had been removed.

TABLE 28. VOLUME OF RED PINE ON PLOT 65, FALL 1939

Fall 1939			
D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	9.8	61	— ²
2	17.2	129	27.5
3	22.4	207	117.0
4	25.8	316	357.1
5	28.2	189	347.8
6	30.2	38	105.3
7	31.8	6	23.4
Total	...	946	978.1

¹ From Chart I, Bulletin 413, of this Station.² Below Limits of Volume Table.

The stand will be thinned and selected trees pruned as needed.

PLOT 66. Western Yellow Pine and Scotch Pine. Area about 1.5 acres.

Planted in April 1908 with western yellow pine two-year seedlings, spaced 5 by 5 feet. There was probably some competing cover at the time of planting as cleanings were necessary in 1919, 1923 and 1924.

In 1923 the western yellow pine averaged 11 feet tall and 2½ inches D. B. H. Losses had amounted to almost 50 percent and, in the spring of 1925, the open places were planted with Scotch pine spaced about 6 by 6 feet.

In 1936 about half the western yellow pine originally planted was still alive, average height 25 feet and D. B. H. 5 inches. On the whole this species has done somewhat better here than on Plot 6 where it was planted in the same year. However, a few trees die every year and it is doubtful if many will be left in another 20 years. Natural pruning is very good on this species, even when entirely isolated. Hurricane damage was very small.

The Scotch pine is quite straight and will be used for pruning experiments on young trees of this species. The western yellow pine will be handled like that on Plot 6, i. e., thinnings will be made from time to time to give the best individuals plenty of room to develop.

PLOT 67. Administration.

PLOT 68. White Pine. Area about 4.3 acres.

Planted in May 1905 with white pine spaced 5 by 5 feet. (Note: The record of this planting, which included Plot 60, reads "white pine planted 5 by 5 feet and 6 by 6 feet, part in furrows and part between furrows, part three-year nursery transplants, part two-year nursery seedlings, and part wild seedlings from Stafford". From an examin-

ation on the ground it seems apparent that a 6 by 6-foot spacing was used on Plot 60 and a 5 by 5-foot on Plot 68. The locations of the areas where the different kinds of stock were used and where the trees were planted "in furrows" or "between furrows" were not described and cannot be reconstructed on the ground).

Counts made in August 1907 showed 98 percent of the three-year transplants, 83 percent of the two-year seedlings, and 60 percent of the wild seedlings were living. The two-year seedlings averaged 13 inches tall and the wild stock 15 inches tall. Three-year transplants on the ridges averaged 25 inches tall, in the furrows 34 inches tall. These figures applied to Plot 60 and Plot 68.

In 1923 the trees on both Plots 60 and 68 averaged 4 inches D. B. H. However, those on Plot 68 averaged 22 feet tall and those on Plot 60, only 19 feet. About this time the tops of the trees on Plot 68 were severely injured in a manner similar to those on Plot 28 and probably by the same agency, namely ice or snow. The injury, for some unknown reason, did not extend into adjacent Plots 59, 60 and 69, all about the same age.

Two permanent sample plots, 90 (thinned), one-half acre in area, and 89 (unthinned) one-quarter acre in area, were established in 1926. The crown injury mentioned above was not apparent at the time the plots were laid out, but by 1930 the crowns on Plot 89 were so malformed that it seemed advisable to abandon the plot. The crowns on Plot 90 were not so seriously injured and, while it is not entirely satisfactory as a sample plot, it is being maintained because it is the only sample plot in white pine on the tract which received a crown thinning.

The table below shows the stand per acre in 1926, and after a hurricane salvage cutting in 1939.

TABLE 29. VOLUME OF WHITE PINE ON PERMANENT SAMPLE PLOT 90, 1926 and 1939

Spring 1926 after thinning				Removed in 1926 thinning		Spring 1939 after salvage cutting			Spring 1939 salvage cutting	
D.B.H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	16.6	50	— ²	..	...	...	...	...	..	...
2	20.3	148	34.0	20	4.6	24.1	10	2.7	..	...
3	23.1	260	148.2	46	26.2	29.8	44	32.1	10	7.3
4	25.4	254	279.4	68	74.8	33.9	124	182.4	32	47.1
5	27.4	238	442.7	58	107.9	36.8	104	258.0	48	119.1
6	29.2	122	341.6	20	56.0	39.0	82	303.0	52	192.4
7	30.8	18	72.9	4	16.2	40.8	98	514.5	36	189.0
8	32.3	6	32.7	..	...	42.0	76	532.0	44	308.0
9	...	...	...	..	...	43.0	34	309.5	14	127.2
10	...	...	...	..	...	43.7	12	134.5	12	134.5
11	...	...	...	..	...	44.2	2	27.4	2	27.4
Total	...	1,096	1,320.9	216	285.7	...	586	2,296.1	250	1,152.0

¹ From Chart I, Bulletin 427, of this Station.

² Below Limits of Volume Table.

That portion of Plot 68 not occupied by sample plots was thinned by the crown method in the winter of 1928-29 and the selected trees pruned to a height of 10 feet.

The hurricane of 1938 completely destroyed about one-half of Plot 68, adjacent to Plot 69 and the Windsor-East Granby highway, and blew down many trees on the rest of the plot. The damage to permanent sample plot 90 was heavy, necessitating the removal of 33 percent of the total volume of wood and 31 percent of the "selected" trees. However, there is still a fairly good stand left and the plot will be maintained.

That part of the stand which remains will be thinned by the crown method and the "selected" trees pruned when necessary. The balance of the plot will be used for other experiments.

PLOT 69. White Pine. Area about 2.6 acres.

Planted in May 1905 with white pine and Norway spruce two-year seedlings, spaced 5 by 5 feet and alternating in the row. It seems probable that at the time of planting there was little or no woody vegetation on the ground. In August 1907, 95 percent of the pine and 64 percent of the spruce were alive; the former averaged 17 inches tall and the latter 11 inches.

In 1913 a fire burned over about one acre near the East Granby highway, killing practically all the trees. Later treatment of this portion of Plot 69 is recorded under Plot 69a.

In 1919 a light weeding was carried out. In 1923, 90 percent of the pine and 60 percent of the spruce were still alive. The former averaged 22 feet tall and the latter, 5 feet. The spruce had been so badly suppressed that it was flat-topped. Most of it was cut and sold for Christmas trees. A few trees had done well and were as tall as the pine. Weevil injury to the pine had amounted to only 30 percent, but the trees were wide-crowned and very limby due to wide spacing. Theoretically, the spacing of the pine should have been 7 by 7 feet. Actually, it was considerably more than this.

In 1928, 200 to 250 trees per acre of the best formed white pines were pruned to a height of 8 to 10 feet, using curved saws and ladders. In 1936 the pruning was extended to 15 to 25 feet. Ten percent of the limbs removed were alive. A light thinning was made at this time. The scars from the 1928 pruning had practically all healed over. There were a few good Norway spruce on the plot. The white pine averaged 38 feet tall and 8.2 inches D. B. H. in 1934.

The growth of the white pine on this plot has been quite rapid but, owing to the wide spacing, the quality of the wood is low. The pruning was delayed too long but the plot will serve as an excellent example of the results of pruning large limbs.

The hurricane of 1938 completely destroyed over one-half of the plot, adjacent to Plots 68 and 70 near the Windsor-East Granby

Highway, and overthrew many trees on the remainder. The moderately damaged part will be continued as an experiment with wide-spaced white pine. The balance will be used for other purposes.

PLOT 69a. Red Pine. Area about 1 acre.

This plot covers that portion of Plot 69 which was burned over in 1913. Planted in the spring of 1920 with red pine three-year transplants, spaced 6 by 6 feet. There were some white pine and Norway spruce from the 1905 planting and these reduced the area planted to red pine.

In 1923, 95 percent of the red pine were alive and averaged 30 inches tall. In 1924 the plot was cleaned of competing hardwoods and, in 1927, 100 Scotch pine were planted in the fall places. In 1932 some of the older white pine, which were crowding the red pine severely, were removed.

Table 30 shows the stand per acre of red pine as of the fall of 1939 after 201 cubic feet of hurricane salvage material had been removed.

TABLE 30. VOLUME OF RED PINE ON PLOT 69a, FALL 1939

D. B. H. ins.	Height ft.	No. trees per acre	Total ¹ peeled vol. per acre cu. ft.
1	7.7	36	— ²
2	14.8	46	8.9
3	21.6	73	40.1
4	25.5	133	147.6
5	27.9	134	245.2
6	29.5	41	111.1
7	30.7	18	67.5
8	31.7	5	25.0
Total	...	486	645.4

¹ From Chart I, Bulletin 413, of this Station.

² Below Limits of Volume Table.

The plot will be thinned from time to time as needed and selected trees pruned.

PLOT 70. Austrian Pine and Scotch Pine. Area about 1.0 acre.

Planted in April 1908 with Austrian pine two-year seedlings, spaced about 6 by 6 feet. Early losses were heavy and, in 1923, only about 25 percent of the trees planted were alive. The average height was 3 feet.

In 1925 Scotch pine was planted on such portions of the plot as were not occupied by Austrian pine and spaced 8 by 8 feet. There was considerable pitch pine and hardwoods on the ground at the time of this planting.

In 1934 the Austrian pine averaged 18 feet tall and 3.3 inches D. B. H. This is very slow growth, even on this site. Such trees as have survived appear healthy but the crowns are thin and narrow. In bark and bud characteristics they are fairly typical of Austrian pine but the needles are twisted and fairly short and, in general conformation, they are quite unlike the typical form of this species.

The Scotch pine has not done well. In competition with older trees it is slender and crooked-boled. Where it had plenty of room to grow, it has produced spreading crowns and crooked stems. Hurricane damage on the plot was moderately heavy.

Release cuttings will be made when needed to favor the Austrian and Scotch pines which are of good form, together with some white pine reproduction which is establishing itself by natural seeding. Some trees from a seeding experiment in 1904, with white oak and bitternut hickory, still persist.

"New Clark" Lot.

This tract of about 10 acres was bought in 1929 to round out the property. In general the land is flat. However there are several bubbling springs in the middle of the piece, the water from which has cut a number of gullies. These join to form a considerable stream which leaves the property at about the middle of the south boundary.

At the time of purchase there was a forest cover over the whole lot. That on the east side was largely oak about 50 years old, while that on the west side was chiefly pitch pine and gray birch 30 to 40 feet tall.

Plots 71 to 75 inclusive, which are described below, were laid out approximately as shown on the map. The balance of the area will be used for experimental purposes as the need for land arises. There was almost no damage to the several experiments from the hurricane, although in some cases the natural cover was disturbed.

PLOT 71. White Pine Underplanting. Area 1.0 acre.

In the winter of 1931-32, a heavy cutting was made in a stand of oak 50 to 60 feet tall, creating openings 20 to 30 feet across between the crowns. Brush was lopped and scattered and the wood removed.

In the spring of 1932 one acre of the thinned area was planted with white pine three-year transplants. A 6-foot spacing was used but, as no trees were planted near stumps or the bases of living trees, the number of trees used was considerably less than for a planting in the open with the same spacing.

The purpose of these operations was to create conditions for the observance of the growth of, and weevil injury to, white pine under a thin, high cover. Each planted tree was tagged, and measurements of height growth and observations on weevil injury are made an-

nually. These measurements and observations will be carried on for a number of years and reported on when the experiment is completed.

PLOTS 72, 73, 74 and 75. **White Pine.**

These plots constitute a series and were laid out for the purpose of studying weevil injury to white pine when planted in openings of different size. Areas: Plot 72, one-sixteenth acre; Plot 73, one-half acre; Plot 74, one-quarter acre; and Plot 75, 1 acre.

In the winter of 1930-31 the cover on these plots, consisting of hardwoods (chiefly gray birch and pitch pine, 30 to 40 feet tall) was removed and the slash piled and burned. A fringe of the original cover at least 25 feet wide was preserved around each plot.

In the spring of 1931 the plots were planted with white pine three-year transplants, spaced 6 by 6 feet. A considerable loss due to Pales weevil was replaced in the spring of 1932 with white pine three-year transplants.

Since establishment, cleanings have been made when needed to keep the plots entirely free of sprout growth. Each tree bears a tag. Observations on growth in height and weevil injury are recorded annually. It is planned to continue these plots for a number of years and to report the results when the experiments are completed.

NOTES ON SPECIES

Following is a list, together with supplemental notes, of the planted species which still form, or formed before the hurricane, some part of the stands described under the various plots. An asterisk indicates that the species also grows naturally on the tract.

Conifers

White pine, *Pinus strobus* L.* Plots 1a, 1, 2, 3, 4, 5, 6, 7, 8b, 11, 12, 15, 16, 17, 20, 21, 22, 24, 25, 26, 27, 28, 29, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42-43, 44, 45, 46, 48, 49, 51, 52, 53, 54, 55, 56, 59, 60, 61, 62, 63, 68, 69, 71, 72, 73, 74, 75.

This species has been used more extensively than any other in the plantings at Rainbow. It is native to the region and, if not subjected to fire, often forms a considerable part of the stand on light soils. It is a valuable component of any stand, but especially on sandy soils where the number of good timber species is small. On such sites it should be increased at the expense of less valuable species.

White pine is easily handled in the nursery and, with ordinary care, plantings show a high survival. Usually, three-year or four-year transplants are considered best for field use but many plots at Rainbow were successfully established with two-year seedlings. Most of the trees were set out in early spring but, on the two plots where fall planting was used, there was also a high survival.

The problems involved in the establishment of white pine plantations are, therefore, negligible. On the other hand, the difficulties encountered during the first 20 to 25 years, in bringing through enough acceptable stems to form a final stand, are considerable. Of the many plantations of white pine set out in Connecticut between 1900 and 1912, few are in condition to produce a good final crop.

Owing to the fact that white pine has been planted at Rainbow on a fairly uniform site and under a wide variety of conditions, there is a better-than-average opportunity to make some general deductions on the factors which have contributed to successes and failures with this species. Some criteria are necessary as a basis for discussion and, in the absence of definite standards, the following is proposed:

At the time of the first thinning (about 20-25 years at Rainbow) there should be between 200 and 400 well-distributed trees per acre which can be favored. These should have straight boles, small branches and deep, narrow crowns. Trees of this type are most often found in stands with an irregular crown canopy, where they are slightly below the dominant trees in height but have not been suppressed or so badly crowded from the side that they have become short crowned. Under such conditions white pine, being fairly tolerant of shade, will make fair growth and respond well when released. Such trees are well protected against weevil attack and, if infested, recover quickly with little or no crooking of the bole.

A number of plots at Rainbow, described in the following paragraphs, illustrate how a desirable stand of white pine may be obtained.

On Plot 12, thinned in 1932, there were, prior to the hurricane, 500 trees per acre of excellent form. The stand was under a birch cover for the first eight years. It received excellent protection against weevil injury below 7 feet and, above this point, recovery from injury was very good. All badly weeviled trees were removed in thinning. It seems evident that the birch helped to produce uneven height growth in the planted trees and a consequent early establishment of dominance which is very desirable.

Plots 20 and 21 were planted to white pine and Scotch pine in 1910, and thinned in 1932 to leave a scattered cover of Scotch pine over the white pine. The cutting was delayed too long and many white pines were badly suppressed. Nevertheless, there are some very excellent trees on these plots.

Plot 25 was planted in 1902 with collected stock of various sizes, the planting covering a period of three years. Losses were fairly heavy, those occurring after 1905 not being replaced. The stand, prior to its destruction by the hurricane, was irregular with more the appearance of a natural than a planted stand. There were more than enough well-formed trees to make a complete stand.

On Plot 27 two age classes of white pine are represented. The older trees were planted in 1904. Many were badly weeviled and were removed in 1932 to favor the younger trees which were planted in 1910. The latter are of good form and will eventually make a complete stand.

There are some groups of excellent white pine on Plot 33 which were planted under an old over-wood of pitch pine. The cover was gradually removed during a period of 15 to 20 years. These groups are quite similar in appearance to natural white pine stands under pitch pine covers. There are other plots containing examples of good white pine stands. These have grown under conditions more or less similar to those described above and will not be referred to here.

Apparently the worst possible conditions for the development of white pine are where the trees grow quite evenly during early life. Weevil injury is usually severe. If the spacing is wide (8 to 12 feet), very few trees escape. Moreover, the crowns are wide and the branches very large. Plots 39 and 69 are good examples of this. Even with a closer spacing (below 6 feet), weevil injury is usually heavy, although recovery from it is much better than with wider spacings. Plot 26 (north end) and Plot 28 are examples. The crowns on the latter were also severely injured by some other agency (probably an ice or snow blanket). Plot 61 is close-spaced but the trees were planted in a low birch cover. There is an excellent stand on the ground but a thinning (made at a loss) was necessary at 20 years.

White pine has grown quite well on most of the plots at Rainbow. In a few places where the site seemed to be particularly poor, as on the west side of Plot 44 and on the north end of Plot 16, the species has either failed or has made almost no growth. Red pine planted with it on Plot 16 has done somewhat better.

Some fertile seed has been borne on the planted trees for 10 years or more. There was a heavy seed crop in 1934 and another in 1938. There are many seedlings of various sizes on the ground and a number of experiments are under way, or contemplated, to replace some of the older, poorer stands with a new crop by natural seeding.

Some suggestions for improvement in methods of artificially establishing white pine stands, based on experience at the Rainbow tract, are:

1. *Plant in pure groups in openings surrounded by cover 25 feet or more in height. The width of the openings should not be over 75 feet.*

2. *Establish two-aged stands, the first planting to be of any fast growing species, which will be eliminated within 25 years, and the second to succeed it by 5 to 10 years, the mixture to be by groups of 30 to 50 trees. This would create a stand made up of irregular groups, which is probably better than mixtures by alternate rows or alternating in the row. More than two age classes could be used if desired.*

3. *Plant under cover and remove the latter gradually, beginning at about the tenth year. A thin, high coniferous cover (pitch pine is excellent) seems to be the most satisfactory but any cover is preferable to open land. The growth of the planted trees will be slower than in the open. Before there is a marked slowing down in height growth and before the leaders become bent or twisted, the cover should be thinned to relieve competition.*

Scotch pine, *Pinus sylvestris* L. Plots 1, 4, 8a, 14, 17, 20, 21, 23, 31, 34, 35, 36, 37, 45, 54, 56, 58, 62, 63, 64, 66, 70. (Scotch pine suffered heavy hurricane damage and, on many of the plots cited, only vestiges of the original stands remain.)

This tree has made the fastest growth of any conifer used on the tract. The stand on Plot 23 (completely destroyed) was the best of this species in Connecticut. Other good stands were to be found on Plots 20, 21, 31, 35, 37 and 56. With the exception of Plot 31 (completely destroyed), these were established by using Scotch pine as a filler in white pine stands five to eight years older. The stands planted since 1920 have, in general, shown much poorer development. Since nothing is known of the source of seed no comparisons can be made on this basis.

As far as can be determined from an examination of the stands and the records of planting and subsequent care, the rather phenomenal development of the species at Rainbow has resulted, at least in part, from planting with a narrow spacing and with little or no overhead competition. Under these conditions Scotch pine has produced reasonably straight stems. Thinnings to prevent too much loss of crown should be made early, probably at about 20 years. With wider spacing in the open, a comparatively few trees tend to "wolf" the area, producing broad crowns with large side branches and crowding out the weaker trees. This was illustrated on Plots 20, 21 and 34, where competition with white pine amounted to very little.

Scotch pine is quite intolerant and, if crowded severely by taller trees, quickly becomes crooked and spindling and soon dies. This is well illustrated on Plots 8a and 63. Early competition with older birch is believed to have been the primary cause of poor development on Plot 14 (completely destroyed).

The plantations at Rainbow indicate that, under the right conditions, Scotch pine will develop reasonably well. However, in a high percentage of plantations established with this species in Connecticut and elsewhere, the stands are worthless from a timber standpoint. The wood from planted Scotch pine is slightly stronger in bending strength than that of planted red pine, but still is quite weak. Under these conditions, the question arises as to its value for forest planting. Its chief merit seems to be that it will grow faster on very poor sites than any other conifer and there it probably can be used to advantage. It may also have some place as a temporary or trainer species if it can be grown cheaply. On Plot 14, which was heavily thinned

in 1932, there is an excellent stand of white pine seedlings, indicating that Scotch pine needle litter forms a favorable seed bed for white pine. On the whole, however, the drawbacks to it are such that it probably should not be used if any other species will serve the purpose.

Red pine, *Pinus resinosa* Ait. Plots 8a, 16, 17, 22, 24, 57, 62, 63, 65, 69a.

Comparatively few stands have been planted with this species at Rainbow. The height growth on Plot 22 showed the poorest site quality for this species of any found in Connecticut. That on Plot 16 was somewhat better, but still rather slow. The species is about equal to white pine in growth under most conditions, although it surpasses the latter on the very poor sites. It grows much more slowly than Scotch pine. Its general form is, however, much better than that of the latter.

Jack pine, *Pinus divaricata* Du Mont de Cours. Plots 30, 46, 47 (all severely damaged or destroyed by the hurricane).

The pure planting of Jack pine on Plot 30 (completely destroyed) was not in satisfactory condition. Early losses were heavy and the increased growing space resulted in wide-crowned trees with crooked boles and large side branches. The same type of development is to be found on Plot 47, where the trees also had too much growing space. On Plot 46 the species was used as a filler in an older stand of white pine and spruce. Here it produced straight boles with small side branches and pruned itself quite well. Moreover, it caught up with the earlier planted species.

In a few places, adjacent to planted plots, Jack pine has seeded in naturally. Here it is quite dense and the trees have long narrow crowns and are straight-boled with small side branches. It would seem that, if properly handled in dense stands, Jack pine may have a considerable merit for forest planting on poor soils.

Japanese red pine, *Pinus densiflora* Sieb. & Zucc. Plots 1, 5, 16, 19, 52.

Of the several plots planted to this species there is not a single instance of satisfactory development and it seems quite apparent that it is unsuited to light sandy soils. If planted in the open it branches profusely near the base, forming many stems. It is extremely intolerant and, with even slight competition, grows crooked. Under all conditions the stems are quite slender. Juvenile height growth is rapid but soon slows down. White pine will outgrow and suppress it within 20 years. The species bears cones very prolifically and fertile seed is produced on trees not over five years old.

Japanese black pine, *Pinus thunbergii* Parl. Plot 54.

This species was used on only one plot and was a complete failure. A few trees persisted for a number of years but developed procumbent stems and were soon crowded out by white pine planted at the same time.

Pitch pine, *Pinus rigida* Mill.* Plots 3, 49.

Two plots were established with this species, one by direct seeding and one by planting. The results were not satisfactory and both experiments have been abandoned.

There is ample evidence on the tract, from stands artificially established and those growing naturally, that this species is an excellent nurse crop for white pine. If the canopy is not too dense, white pine will grow through it without serious injury to the tops from "whipping", and with a high degree of protection from weevil injury.

Austrian pine, *Pinus Laricio* var. *austriaca* Loud. Plots 1, 24, 70.

There is too little of this species at Rainbow to furnish much data on its behavior as a forest-grown tree. Moreover, several different strains were used. The development of that on Plot 24, which is typical of the species, has about equalled that of red pine planted on the same plot. On Plot 70 the trees are decidedly atypical with narrow slender crowns and sparse twisted needles. Here, growth has been very slow. On Plot 1 the trees are intermediate between those on the other two plots. Here also growth has been moderately slow. The tree seems to have little to commend it over indigenous species for forest planting on sandy soils.

Corsican pine, *Pinus Laricio* Poir. Plot 45.

Not more than a hundred good trees survived on Plot 45 out of more than 4,000 planted in 1910. They are entirely open-grown and hence no criterion of the behavior of the species in forest stands.

Growth under these conditions has been rather slow. The crowns of the trees are very dense and the needles stiff and sharp-pointed. In common with Austrian pine, the species seems to have little to commend it for forest planting on sandy soils.

Mountain pine, *Pinus montana* Mill. and Mugho pine, *Pinus montana* var. *mughus* Willk. Plots 17, 34, 45.

It seems probable that all the mountain pine planted at Rainbow was the non-arborescent Mugho variety. On Plot 34, where it was planted with Scotch pine, it was quickly shaded out. On Plots 17 and 45 it did well as a shrub but has been replaced by other species which attain tree size. Many of the original trees were sold for ornamental plantings. On Plot 45 there are thousands of seedlings of all sizes, seeded from the trees originally planted.

Western yellow pine, *Pinus ponderosa* Laws. Plots 6, 66.

This species grows in many places in the West in open park-like stands in regions of scant rainfall. It has not done well at Rainbow. Early losses were heavy and there has been a gradual loss since the trees became established. The reason for lack of success is not entirely clear. Too much competition seems to be the most logical reason. According to eastern standards, competition has never been very keen but, because western yellow pine grows naturally in open stands, it may have been more than the trees could stand.

Western yellow pine is very intolerant of shade and prunes itself well, even in the open. Growth at Rainbow has been variable but, on the whole, rather slow. Its value for reforesting thin sandy soils is relatively low.

Douglas fir, *Pseudotsuga Douglasii* Carr. Plots 1, 17, 38, 47.

Very little of this species has been used. For a number of years many of the trees were killed back each winter but, more recently, they seem to have become acclimated and are no longer suffering this type of injury. Growth has been extremely variable, some of the trees equalling white pine in height at 35 years, while others are little more than shrubs.

The tree is very tolerant and seems to be able to stand severe crowding and still maintain a fair rate of growth. While Douglas fir is a very beautiful tree, it probably has relatively little value for reforesting sandy soils.

Balsam fir, *Abies balsamea* Poir. Plot 13.

Less than a hundred trees of this species have been planted. Those that have survived are doing fairly well and indicate a rather remarkable adaptation of a moisture-loving species to a site which is decidedly xeric. It is not, however, considered a suitable species for planting on very light soils.

European larch, *Larix europaea* deC. Plots 1, 17.

This tree was planted only on Plot 1 where most of it was destroyed by fire. A few of the trees which survived, and a few others left in the old nursery rows on Plot 17, have done exceptionally well, indicating that the species might be worth trying again on the tract.

Norway spruce, *Picea excelsa* L. Plots 1a, 8a, 8b, 10, 13, 32, 33, 41, 42-43, 44, 46, 47, 69.

The success or failure of this species on the Rainbow tract has depended largely upon its getting well established. When planted on sites without cover, Norway spruce will persist for a number of years but will make no growth and, in competition with another

planted species or with natural cover which comes in later, may be entirely suppressed and killed out. Two examples illustrating this are Plots 8a and 69. Here the spruce was planted with pine in the open. In both cases it made little or no growth during the first five years after planting and was soon suppressed.

At a number of other places, notably on Plots 10, 13, 42-43 and 44, spruce was planted under cover, either pure or with another species. Under these conditions, the spruce became well rooted and its subsequent development has depended largely on the handling of the cover.

Spruce is quite tolerant and will persist for a considerable time under fairly dense shade. If it has not become flat-topped from too much suppression, it will respond quickly to releasing and grow at a rapid rate. This is well illustrated on Plots 10 and 13. Flat-topped trees in the same stands responded very little during the five years following release.

Apparently a high cover of older trees is better than low cover while the spruce is becoming established. The best Norway spruce on the tract is on Plot 42-43, where it was planted in 1906 in alternate rows with white pine under a cover of old pitch pine and hardwoods. This cover was removed between 1911 and 1926. It had held back the growth of the white pine more in proportion than that of the spruce and sheltered the latter during the early critical years. By 1930 the pine had assumed dominance in the stand both in numbers and position. Most of the spruce appeared healthy but was rapidly being overtopped. A thinning in the pine in 1932 released the spruce, which has responded quite well and, in some cases, is as tall or taller than the pine.

Norway spruce is considered one of the most satisfactory exotics for forest planting in the east. It is reasonably free from insect and fungous enemies and does well on most sites. On very poor soils it needs protection during the first 10 to 15 years after planting.

White spruce, *Picea canadensis* Mill. Plot 18.

This species was planted only on Plot 18 and here under very unfavorable conditions. Judged from the very limited data available, it seems probable that the behavior of this species on sandy soils should not be greatly different from that of Norway spruce.

Hardwoods

Red oak, *Quercus rubra* L. Plots 4, 17, 40, 48, 50, 51.

This species has been used with indifferent success on a number of plots. On Plots 40 and 50, where it was in pure stands, it was almost a complete failure. On Plots 4, 48 and 51, where it was mixed with white pine, it either has crowded out the latter or has been crowded out. Its behavior has probably been due in part to damage

in early life by rodents which kept the trees cut back. However, even where it is at its best, its form is not as good as on better soils. The trees tend to fork near the ground and do not prune themselves well. It is not considered a satisfactory species for light sandy soils.

Black locust, *Robinia pseudoacacia* L. Plots 57, 58, and on many other plots by natural seeding.

Without exception, this species has made faster growth than any other used on the tract. Two crops of cordwood have been cut from Plot 58, which is the only plot on which it has not been replaced by other species. The second crop of sprouts now averages 25 feet tall.

The trees in the original stand, and in the first stand of sprouts, were very badly infested with locust borer and were cut for this reason. The present stand of sprouts, which has grown very fast, seems to be reasonably free of this pest and there is some prospect of raising a fair crop of posts from them.

Since the species has a considerable value as a soil builder, it may be worth raising on thin soils even if the trees amount to little.

Chestnut, *Castanea dentata* Borkh.* Many plots.

Chestnut was used very extensively in the early experiments. It also grew naturally on the tract in considerable abundance. Due to the ravages of the chestnut bark disease, its use was discontinued and it was replaced by other species. However, it has been very persistent and is still to be found, mostly as an understory, on many plots. Much of it has been killed back repeatedly but there are many trees of varying size which appear to be in fairly good condition.

Other Species

The following tree species have been planted or seeded experimentally but have either failed completely or are present only as isolated individuals. An asterisk indicates that the species grows naturally on the tract.

Ash, green, *Fraxinus pennsylvanica* var. *lanceolata* Sarg.

Ash, white, *Fraxinus americana* L.

Basswood, *Tilia americana* L.

Beech, *Fagus americana* Sweet.*

Birch, black, *Betula lenta* L.

Birch, gray, *Betula populifolia* Marsh.*

Catalpa, *Catalpa* sp. L.

Cedar, red, *Juniperus virginiana* L.

Cottonwood, *Populus deltoides* Marsh.

Hickory, bitternut, *Carya cordiformis* K. Koch.

Maple, Norway, *Acer platanoides* L.

Maple, sugar, *Acer saccharum* Marsh.

Oak, white, *Quercus alba* L.*

Tulip, *Liriodendron tulipifera* L.

In addition to the species listed above, others growing naturally on the tract are:

Aspen, large toothed, *Populus grandidentata* Michx.

Aspen, trembling, *Populus tremuloides* Michx.

Cherry, black, *Prunus serotina* Ehrh.

Cherry, choke, *Prunus virginiana* L.

Cherry, pin, *Prunus pennsylvanica* L.

Maple, red, *Acer rubrum* L.

Oak, black, *Quercus velutina* Lam.

Oak, chinquapin, *Quercus prinoides* Willd.

Oak, scarlet, *Quercus coccinea* Muench.

Oak, scrub, *Quercus ilicifolia* Wangh.

Sassafras, *Sassafras officinale* Nees & Eberm.

PLATE I

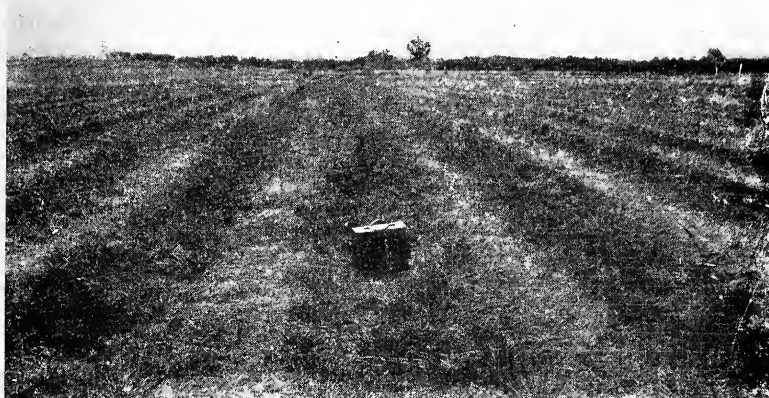


Figure a. Plot 23 in 1903, a year after planting with pine seedlings. Note old furrows and ground cover typical of the area.



Figure b. White pine after thinning and pruning. Plot 15 in 1937.

PLATE II



Figure a. White pine after thinning. Plot 7 in 1937.

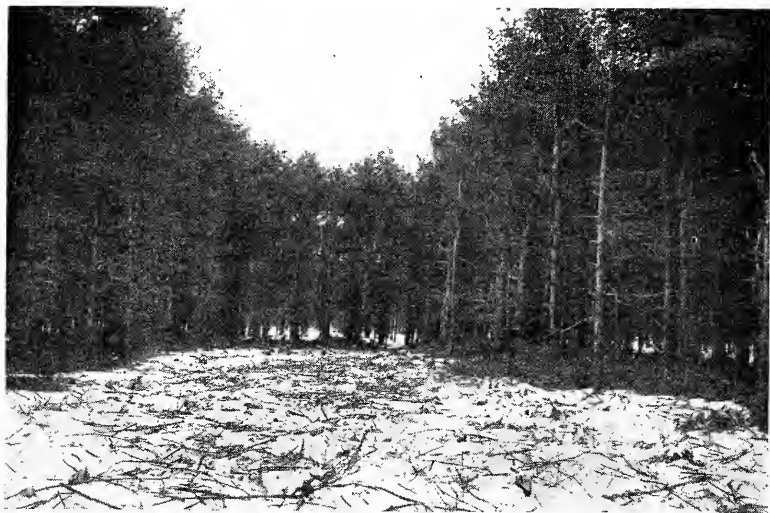


Figure b. White pine showing malformation of boles, probably caused by an ice or snow blanket. Plot 28 in 1936.

PLATE III



Figure a. Scotch pine and white pine mixed plantations after hurricane. Plots 35 and 36 in October 1938.



Figure b. Red pine pure plantation after hurricane. Plot 24 in October 1938.

PLATE IV

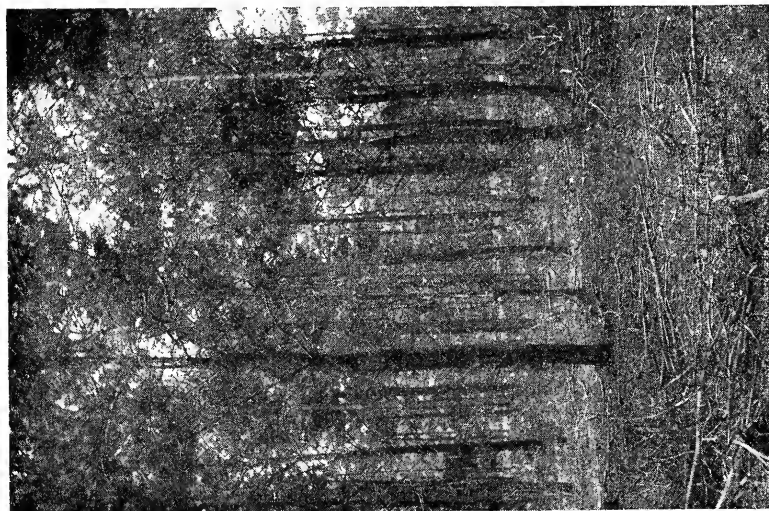


Figure a. Scotch pine and white pine, unthinned; white pine mostly suppressed. Plot 37 in 1938.

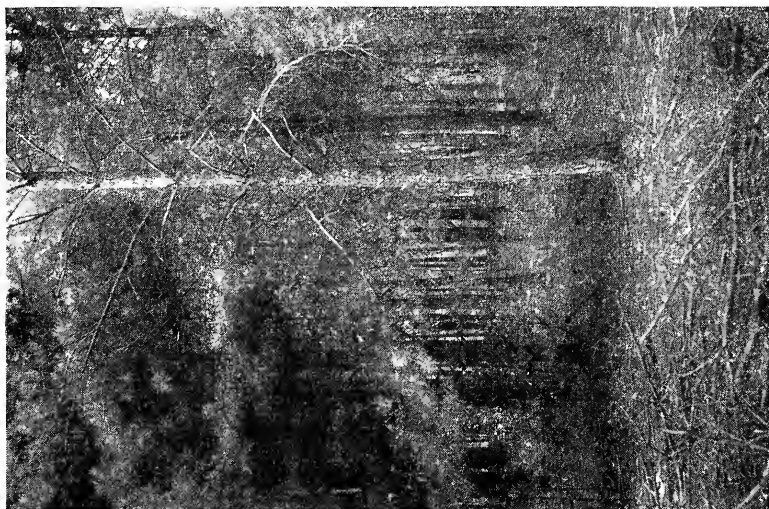


Figure b. Scotch pine and white pine 10 years after thinning. Plot 36 in 1938.

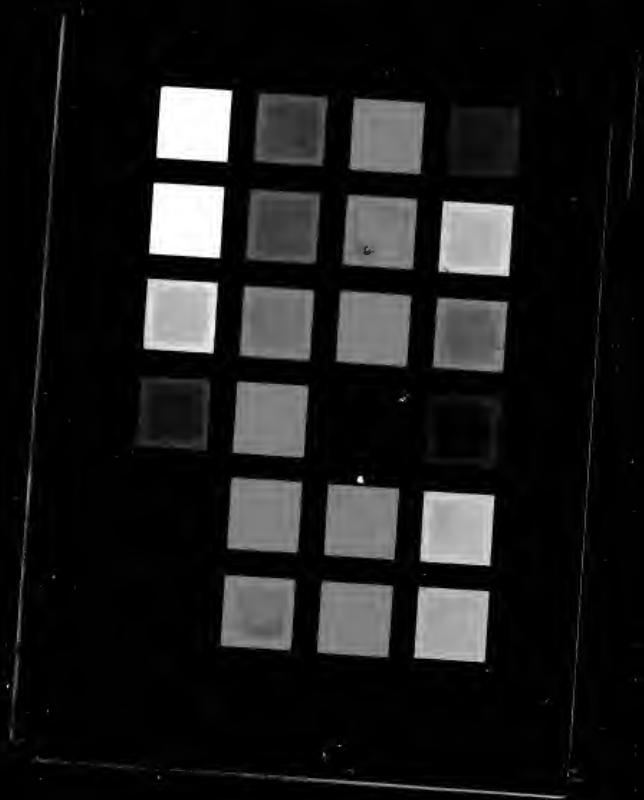


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